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Stocking control of lodgepole pine in the Sleeping Child burn

Kelsey S. Milner
The University of Montana

STOCKING CONTROL OF LODGEPOLE PINE

IN THE SLEEPING CHILD BURN

By

Kelsey S. Milner

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Approved by:

George M Blake
Chairman, Board of Examiners

Dean, Graduate School

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Ten years of stocking control efforts in young, overstocked stands of fire origin lodgepole pine (*Pinus contorta*) were studied. The objectives were to provide: (1) a detailed record of treatments; (2) an evaluation of the treatments with respect to securing a desired stocking level; and (3) recommendations for stocking control in similar stands.

District records, personal experience with the treatments and assistance from a few district employees provided the detailed record. Treated stands were stratified by treatment type, habitat type and year of entry. Thirteen stands were sampled. Height, age and crown width data were collected from stems in each of three residual classes: leave trees, excess trees, and lower live limb turnups. Up to 5 years of height and crown width measurements were made on individual stems in each class. Untreated stands over a range of densities and habitat types were also sampled. These data were used to describe total height, age distribution, annual height growth since treatment and the change in form since treatment of stems in each residual class in each stand. Crown closure of leave trees was predicted and height differences among residual classes at that time were estimated. Between stand differences were interpreted with respect to treatment type, habitat type and year of entry.

Results indicate that excess trees and lower live limb turnups pose a distinct threat to the success of early stocking control treatments. Generally, the younger the stand the greater the threat as such stands have a large component of small young stems which are the source of excess trees and live limb turnups. Excess trees and live limb turnups appeared to respond quickly to increased growing space. Leave trees showed no response indicating no loss of growth prior to treatment. It is recommended that entry in similar stands be delayed until seedling establishment ceases, shading out of lower live limbs occurs, and the frequency of stems less than 12" high is reduced. Entry after stand age reaches 15-17 years is suggested.

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INTRODUCTION

In August of 1961, the Sleeping Child fire burned over some 28,000 acres of forested land in the Sapphire range of the Bitterroot Mountains southeast of Darby, Montana. Nearly $2 million were spent on fire suppression efforts. Impressive as a fire control problem, the fire's effects quickly became the focus of management activities of equal magnitude. The fire virtually eliminated the mature subalpine fir (*Abies lasiocarpa*), white bark pine (*Pinus albicaulis*) and lodgepole pine (*Pinus contorta* var. *latifolia*) which occupied the site prior to the fire. Such large scale denudation presented the immediate threat of erosion damage to the seven drainages involved. To combat this threat, terracing, grass seeding and tree planting operations were carried out in some areas. However, the most efficient preventative was supplied by the dense natural regeneration of lodgepole pine which appeared on some 18,000 acres of the burned area. Densities in the neighborhood of 160,000 stems/acre were observed on some sites.[1]

Such "dog-hair" conditions are typical of fire origin lodgepole pine stands in the Rocky Mountains (Critchfield 1957, Lotan 1967, Brown 1975). The predominantly serotinous cone habit of the species in this area

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[1]Brian Avery, "Sleeping Child Burn Management Plan," 1977, p. 5.

provides an abundant supply of stored seed which can remain viable up to several decades (Critchfield 1957). Where lodgepole is a dominant seral species, considerable quantities of serotinous cones with viable seed accumulate in the canopy. In the absence of fire and under the shade of a canopy the cones remain closed and succession proceeds toward the climax condition (Pfister 1975). The occurrence of fire provides the temperatures needed to melt the resin bonds of the serotinous cones. The breakage of the resin bonds is followed by the flexing of cone scales in response to changes in the moisture content of the cones. As the cone scales flex, seed is released. The fire simultaneously removes competing vegetation and provides bare mineral soil needed for successful germination and seedling establishment. The large quantities of stored seed released onto the prepared seed bed give rise to the overstocked condition (Clements 1910, Mason 1915, Horton 1956).

In the case of the Sleeping Child fire, excessive fuel loading was caused by a mountain pine beetle (Dendroctonus ponderosae) epidemic in the late 1920s and early 30s. The beetle swept through thousands of acres of mature, seral lodgepole pine forests. Over the next 30 years the dead trees gradually fell to the forest floor. Fuel loading reached 80 tons/acre by 1961.[2] Vigorous fire control efforts by the Forest Service prevented any significant fuel reduction by burning during this time. Finally, in 1961, hot dry weather, high winds and a single lightning strike combined to produce a fire of sufficient intensity to resist suppression efforts. The lodgepole pine-mountain pine beetle-wildfire cycle completed

[2] Avery, p. 12.

one revolution and began another with the establishment of the present overstocked stands.

The control of overstocked stands of lodgepole pine has received considerable attention. A substantial percentage of the seedling-sapling stands (25% in western Montana) are severely overstocked and the perennially unfavorable cost-benefit ratios of thinning have kept management of these stands from progressing (Cole 1975). Increased utilization standards, projected future demands for timber products, and emphasis on other forest uses have combined in recent years to justify stocking control efforts, however.

With respect to timber objectives, the benefits of thinning seem well established. Wickstrom and Wellner (1961) estimated that four times as much usable wood could be produced in thinned stands as in unthinned stands. Cole (1975) using maximum MAI of total cubic volume as the main criterion for assessing thinning effects, has modeled stand growth for a variety of stand-site-treatment combinations. He determined that total cubic volume yield is increased by a single early thinning in all densities down to about 300 stems/acre, when viewed at near rotation length time periods. Alexander (1960) showed that thinning: 1)reduced mortality, 2) increased average annual diameter growth, and 3) increased net basal area growth per acre. Similar results have been obtained in numerous other studies (Quaite 1950, Smithers 1957, Barrett 1961, and Barnes 1958). In light of the acreage occupied by lodgepole pine (21 million acres in the U.S., 49 million acres in Canada), substantial increases in wood production could be realized by implementing appropriate thinning schedules.

Forage for wildlife and livestock can also be increased, at least temporarily, by thinning. Favorable changes in volume and composition of understory vegetation should occur (Dealy 1975). Production increases have lasted for as long as 20 years in some stands. Dealy estimated that thinned 47-year-old stands of lodgepole pine in central Oregon produced from 300 an 1,000 percent more understory vegetation than before thinning. If stocking levels can be reduced successfully in very young stands of lodgepole pine substantial increases in forage can be expected.

Dahms (1971) observed,

> "The real payoff from pre-commercial thinning comes from getting the trees that will eventually provide the usable wood in possession of the site at the earliest possible moment. The greater response of young trees to increased growing space and the relatively short lifespan of lodgepole pine are additional reasons for getting the pre-commercial thinning job done as early in the life of the stand as possible."

The Forest Service initiated stocking control activities in the Sleeping Child Burn in 1965. A contract was let for the hand pulling or hoeing of lodgepole pine seedlings of 378 acres in the Cameron drainage. The contract was terminated for reasons of non-performance in 1967. Excessive numbers of seedlings, thick grass and resprouting stumps were listed as reasons for non-performance. The difficulty in securing a desired stocking level that plagued that first contractor has been characteristic of most subsequent thinning operations. Mechanical operations were then abandoned in favor of hoped-for success with chemical treatments. Various chemicals were tested for suitability and the final choice Dacamine 4-D was used to treat some 1,600 acres in the Rye and Cameron drainages in

1969. Difficulties in application of the chemical led to mixed success in initially attaining the desired stocking levels, though the cost per acre was substantially less than that for mechanical methods. Further chemical thinning was programmed for 1970 but unanswered questions concerning environmental impacts halted the project before the 1970 field season. Hand operations began again in 1974 and have continued to the present. By 1977 a total of 4,300 acres had been thinned by all methods at a cost of $575,000.[3]

The lack of guidelines for thinning such young, over-stocked stands had made the treatments, at least in part, experimental. For example, the physical and economical impossibility of removing all lodgepole pine stems (trees, seedlings, lower live limbs) other than leave trees, necessitated the establishment of limits for these categories. Little information existed as to what these limits should be for a given stand without negating the desired effect of stocking reduction. The change in stand characteristics through time and from site to site further exacerbated the problem of setting appropriate limits. In addition the pattern and intensity of the hand thinnings have been varied in efforts to meet multiple management objectives. Uniform spacings, dominant tree and crop tree techniques have been applied to a range of stand and site combinations.

With respect to timber objectives, a stocking control treatment will be successful to the extent that the crop or leave trees fully tap, for the desired period of time, the growth potential of the site. Success will

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[3]Avery, p. 7.

be reduced to the extent competing vegetation prevents full utilization of this potential. In the Sleeping Child Burn the primary threat is from other components of the residual. Alder (Alnus sinuota) and ceanothus (Ceanothus velutinus) are widespread but rarely dominate the lodgepole pine. Small stems, missed during treatment and lateral branches left on cut stumps constitute the potential competition to the crop trees. For the rest of this paper the following definitions will be used in reference to the components of the residual stand:

1) Leave Trees - those stems designated to receive the growth potential of the site.

2) Excess Trees - those stems not eliminated during treatment. These are mainly young and suppressed individuals.

3) Lower Live Limbs (LLL) - lateral branches left on the mainstem which have turned up and are functioning, apparently, as normal trees.

The experimental nature of these programs and the substantial investment made in them demand that an evaluation of the success of the treatments be made. The objective of this study is to provide such an evaluation. The specific objectives are:

1. To provide a record of the stocking control treatments applied in the burn area. The record to include: management objectives, treatment selection, treatment specifications, problems encountered, and recommendations made.

2. To evaluate the success of the treatments in securing and maintaining desired stocking levels. The treatment evaluation will consist of several parts. First, a description of the residual in treated stands

consisting of the age, height and height growth characteristics for each component class. Second, an estimation of the response of each component class in each stand to the increased growing space. Third, an estimation of the years until crown closure and the projected heights of the LLL's and excess trees at that time.

3. To recommend treatment specifications appropriate for stocking control of young, overstocked stands of lodgepole pine similar to those stands found in the Sleeping Child Burn.

Chapter 2

PROCEDURES

Treatment History

From the Sula and Darby Ranger Districts I obtained all documents pertinent to the stocking control programs. The resulting file contained maps, intra-agency reports and memoranda, public notices and impact statements. I then melded these items into a single narrative detailing the Sleeping Child Burn thinning projects over the years 1965-1977. The various location maps from the two districts were used to construct a single map delineating the location of all stands treated since 1965. A list of all treated stands showing treatment type, year of treatment, stand acreage and labor source was made to accompany the map.

Treatment Evaluation

Sampling Procedures

Stand selection. Stands were defined to be areas of reproduction one acre or larger, on a single habitat type, with uniform slope and aspect, in which only a single entry had been made. Records, maps, and my personal experience with the stocking control efforts provided the population of sample stands.

Type of treatment, site and year of entry were assumed to be the major sources of variation in the ultimate success of a stocking control treatment. Stands were selected so as to cover the range of combinations in these factors. Since the central purpose was to measure the growth of the 3 components of the residual under a particular combination of factors, if a choice existed I selected a stand well represented in all three components. Stands close to roads were also given preference over those more removed.

For ease of presentation, stands were identified by a 4 digit code representing a combination of the factors: treatment type, habitat type, and year of treatment. The key to the code follows:

Stand Code Key

Habitat Type	Code	Treatment Type	Code
ABLA/MEFE	1	7 x 7	1
ABLA/XETE	2	10 x 10	2
PSME/VAGL	3	12 x 12	3
PSME/CARU	4	Chemical	4
PSME/SYAL	5	Dominant	5

Year of treatment, which translates into stand age, is simply the last two digits of a given year. So, for example, a stand on a PSME/CARU h.t. treated with a uniform 10' x 10' spacing in 1974 is identified by the code 4274. Table 1 shows combinations of the factors sampled, representing 13 stands.

Plot location. Stands were sampled by plots located randomly along transects chosen so as to ensure coverage of typical portions of the stand. Plot centers were located by pacing a distance determined by digits taken from a random number table. Multiple points of entry were used when more than one transect was established.

TABLE 1

List of Sample Stands

Treatment Type		Year of Entry	(age of stand)	Habitat Type	I.D.
Chemical	12' x 12'	1967	(6)	ABLA/MEFE	1467
				ABLA/XETE	2467
Mechanical	7' x 7'	1974	(13)	ABLA/MEFE	1174
				ABLA/XETE	2174
		1970	(9)	ABLA/XETE	2170
	10' x 10'	1974	(13)	PSME/CARU	4274
				PSME/VAGL	3274
		1976	(15)	ABLA/MEFE	1276
				ABLA/XETE	2276
				PSME/VAGL	3276
	12' x 12'	1975	(14)	ABLA/MEFE	1375
	Dominant	1974	(13)	PSME/VAGL	3574
				PSME/SYAL	5574

Plot Size. The parameters to be estimated were for classes of stems, and were not referenced to any unit area. Plot size varied according to the frequency of stems in each class. Once plot center was established, I moved in an expanding spiral until the desired number of stems in each class was encountered.

Fixed area (1/300 acre) plots were used in some stands to obtain per acre estimates of density (trees/acre) and to determine height class distributions. For these plots, plot centers were located at 1 chain intervals along subjectively chosen transects.

Sample Size. I specified an initial desire that the parameter estimates be within 20% of the true mean with 95% confidence. Of the several parameters to be estimated (mean H/CW, mean diameter, and mean height) I chose basal diameter of excess trees as being representative of the variation and determined the required sample size from the formula:

$$n = t^2(\alpha, d.f)(c.v)^2/A^2$$

where: $t(\alpha, d.f.)$ = t value for appropriate d.f., a 2-tailed test, and

$\alpha = 0.05$

c.v. = coefficient of variation = $s/\overline{x}$, and

A = allowable error, in percent

n = sample size

From the measurements on several 50^{th} acre plots in the first sample stands I calculated n = 25. I generally terminated a plot after I measured 4-6 stems in each component class - thereby insuring at least 4 sample points per stand. Sample size was considerably below 25 on some stands for some component classes, as accuracy was sacrificed for breadth of the data base.

Tree Measurements

Age. A common age of 17 years was assumed for all leave trees. This assumption was based on the leave tree selection process (pick the largest and most vigorous), known date of stand origin 1961, and an assumed high correlation between size and age. Periodic aging of leave trees supported this assumption. Excess trees were aged by cutting them at ground level and counting rings. Cut stump age was measured for LLL's. The age at point of attachment was not taken since the determination was difficult due to distortion of growth patterns by the upturn, and the cut stump age had greater utility. Maximum stump height specifications[1] and a tendancy

[1] Most contract specifications allowed a maximum stump height of 8".

for thinners to cut near ground level in an effort to eliminate LLL's assured that the tree age of most LLL's was within a couple of years of stump age at time of treatment.

Height. Measurements of total height were made for the current year 1978, and for the preceding 5 years or to the time of treatment, which ever came first. The height at any given year was determined by measuring to the appropriate whorl on the mainstem corresponding to the maximum height attained by a stem in a given year. See Figure 1 for illustration.

Height measurements for leave trees were made to the nearest decimeter with a calibrated aluminum pole. Excess trees and LLL's were measured to the nearest centimeter with a meter stick. All measurements were made on the uphill side.

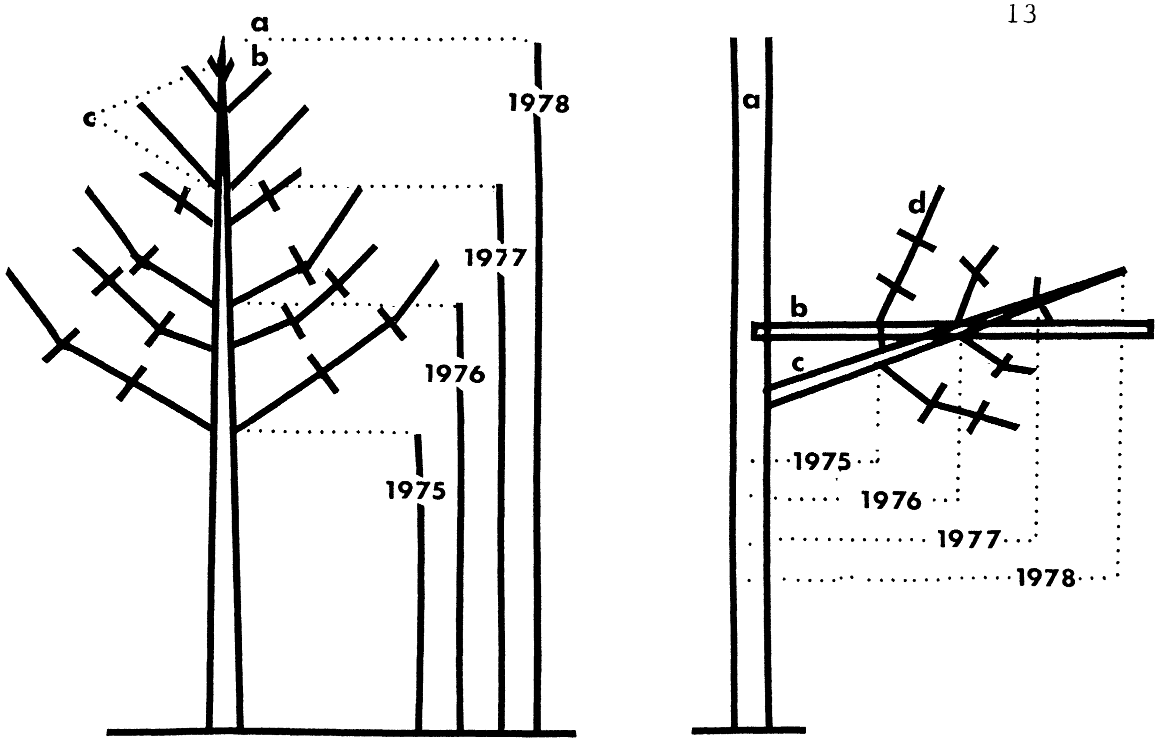
Crown width. Crown width was taken as the average of four perpendicular measurements taken in the zone of greatest crown diameter. Measurements of crown width were made for the current year, 1978, and for the preceding 5 years or to the time of treatment, which ever came first. See Figure 1 for illustration.

Crown width measurements for leave trees, excess trees, and LLLs were made to nearest centimeter with a meter stick held perpencidular to the mainstem center. Measurements were made to the appropriate whorl on the lateral.

Height to lowest live limb. In unthinned stands, the height to the lowest live limb was measured on the first four stems encountered in each quarter of the 1/300 acre plot.

Plot Measurements

Slope and aspect of the general plot local were measured, by a clinometer and compass respectively, on all variable radius plots. The habitat type (Pfister 1977) of a plot and surrounding area



Height Measurement

a = Polycyclic shoot
b = Lateral bud from previous year
c = Expanded polycyclic shoot

Crown Width Measurement

a = Mainstem
b = Meter stick ⊥ to (a)
c = Primary Lateral
d = Secondary Lateral

Height measurements were made to the appropriate whorl on the mainstem. The whorl corresponding to the maximum height growth in a given year was determined by: (1) noticeable color change of bark in last 3 years; (2) persistant bud scale scars at base of terminal buds, visable for 3-4 years; (3) large size of whorls from lateral buds not elongated during initial polycyclic shoot elongation - (b) above, and (4) correspondance of age estimates obtained by working down mainstem and inward on major laterals. (Lanner and Van Den Berg 1975).

Crown width was taken as the average of four lateral measurements. The lateral of greatest extension was measured first followed by the opposite and two perpendicular laterals. Not all laterals were necessarily of the same whorl, though that was the usual case.

Figure 1

Measurement of Height and Crown Width

of Residual Stems

was read from a map detailing the habitat types found in the Sleeping Child Burn.

Analysis

Age. For each sample stand the means and standard deviations of excess tree and LLL ages were calculated and relative frequency histograms of 2 year age classes developed for each component class. The means and histograms are discussed and interpreted with respect to stand history and treatment type.

Height. The means and standard deviations of the heights of each component class, for each year measured, were calculated for each stand. These means were used to describe height characteristics of the sample stands immediately following treatment and at the time of the study, and to construct mean height differences between component classes within each stand for each year sampled. Differences among stands in the height differentials created are discussed with respect to treatment type, site, and year of entry.

For LLL's, relative frequency histograms of 5 cm height classes were prepared for each stand. These distributions are discussed with respect to stand and site characteristics.

Height growth. Annual growth rates of individual stems were averaged to produce mean height growth rates for each component class in each stand. These growth rates are compared among classes within and between stands.

Height to lowest live limb. The mean height to the lowest live limb was calculated for each plot taken in unthinned stands. The mean heights were plotted against stems/plot to demonstrate the relationship between crown recession and density.

Small stem frequency. Estimates of stand density (trees/acre) and the number of stems/acre less than 12" high were made from U.S.F.S. stand exams taken in untreated stands. A plot of these data was made to illustrate the relationship between small stem frequency and stand density.

H/CW ratio. The ratio of height over crown width (H/CW) was selected as the response variable. For each stem measured, the H/CW ratio was formed for each year in the time period sampled. Individual stems in each component class, then, housed up to 5 values of H/CW, from time of treatment, unthinned condition, to 1978. Yearly means and variances were then calculated for H/CW for each component class within each stand. The magnitude and the change through time of this mean provide the basis for analyzing the response to treatment of each component class.

Several assumptions concerning the independence of the H/CW ratio from size and site and its dependence on density were investigated. The sample correlation coefficient, r, between H/CW and diameter for leave trees, was used to test the strength of the relationship between H/CW and size. The ANOVA was used to test the null hypothesis of no difference in the mean H/CW ratio[2] for leave trees in stands on 4 habitat types. Plots of mean H/CW vs. stems/plot and mean H/CW vs. time were made to demonstrate the relationship between H/CW and density.

Regression analysis was used to investigate the rapidity with which the components of the residual responded to the increased growing space. For each component class in each stand the H/CW ratios were regressed over time (1973-1978) using the simple linear model $\hat{Y} = b_0 + b_1X$, where $\hat{Y}$

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[2]A level of significance of $\alpha = 0.05$ is used in all statistical tests performed in these analyses.

was the predicted H/CW ratio and X = time (1973 = 1, 74 = 2, ... , 78 = 6). The magnitude of the b_1 coefficient, or the slope of the regression line, represents an approximation of the speed with which the mean ratio changes over time. The sign of the b_1 coefficient indicates the direction of change in the H/CW ratio.

Height differences at closure. Prediction equations of the form $\hat{Y} = b_0 + b_1X$, where $\hat{Y}$ = predicted crown width and X = height, were developed by simple linear regression techniques for the 5 major spacings sampled.[3] The 1977 height and crown width measurements for leave trees, grouped by spacing, were used in the estimation of the b coefficients.

Analysis of covariance (Freese 1964) was used to test the null hypothesis of equality of b_1 coefficients for those cases where significant regressions were obtained. In the event the null hypothesis was rejected, a Newman-Kuels multiple comparison test was made to locate the differencees. Those data supporting equations which did not differ significantly in the b_1 coefficient were pooled and a single prediction equation formed.

By substitution in the pooled prediction equation the crown width necessary to achieve closure[4] in a given spacing was used to predict

[3]The major spacings were: (1) chemical 12' x 12'. This treatment frequently left leave trees in clumps and hence is separated from the other 12' x 12' spacings, (2) Dominant tree. This treatment generally created a 3'-5' spacing, (3) 7' x 7' uniform, (4) 10' x 10' uniform, and (5) 12' x 12' uniform.

[4]Closure is defined here as that event when the crowns of the leave trees in a square spacing meet. This event is assumed to correspond roughly to the end of the open grown condition.

the corresponding leave tree height. The average leave tree height in the stand and the average height growth rate was then used to estimate the number of years required for such a height, and hence closure, to be attained.

The height and height growth rates of excess trees and LLL's were then used to estimate heights for those stems at the end of that time period. The mean heights of excess trees and LLL's, in a given stand, were estimated as follows:

(1) assume excess trees and LLL's will attain height growth rates comparable to those measured for leave trees in 1977.

(2) compute average yearly increase in height growth rate: Δ rate = 1977 difference in rate/difference in age. Differences refer to leave trees.

(3) successively increment height growth by the amount calculated in (2) through the time interval equal to age difference.

(4) sum yearly increments through time interval, add maximum rate for balance of time to closure, and add to 1977 height to give total height at closure.

Calculations for excess tree and LLL height at closure can be seen in table 24, appendix F.

The mean height differences at closure between leave trees and excess trees and LLL's were then found by subtraction for each sample stand. The variability in the height differences, as seen through a simple presentation of means, among the sample stands was then interpreted with respect to treatment type and year of entry.

Chapter 3

RESULTS AND DISCUSSION

Treatment History

Stocking control programs were begun in 1965 with the letting of a contract to Hinze Forest Contracting to hand pull and hoe 378 acres in the Cameron Creek drainage. At this time the stands were approximately four years old and stocking was estimated at 3-5,000 stems per acre. Seedling heights ranged from 1-18 inches. Only 35 acres were successfully completed and the contract was terminated for reasons of non-performance in May 1967. Failure was due to: (1) the large number of seedlings, (2) thick grass which camouflaged the small seedlings, and (3) the tendency of of severed stumps to resprout. The third item is probably a reference to the growth of live limbs left on the cut stump rather than to actual resprouting. In this study I found no evidence of such resprouting in stands treated since 1970.

In the fall of 1965, prior to the default of the Hinze contract, Wright Tree Service contracted to thin seedlings on 651 acres in the Martin Creek drainage. Similar problems were encountered and in August of 1966 the contractor submitted a request to employ chemical thinning methods. Work was suspended on the contract until a study by the Forest Service could be completed.

In June of 1966, the Forest Service initiated a study to test the feasibility of using chemicals to reduce stocking. The objectives were:

(1) to determine if dense stands of lodgepole pine seedlings could be chemically thinned to a desired spacing for $30 per acre, and (2) to find the best chemical. The study took place in the Rye Creek drainage in an area where seedlings were from 1-5 years old, 1-18 inches tall, and averaged approximately 18,000 per acre. Snags, down fall and grass covered the slopes which ranged from 30-70 percent. Six chemicals were tested. One chemical was selected for use on a large plot (118 acres) to determine cost per acre. Smaller plots (¼-1 acre) were used to test effectiveness of the different chemicals. Clear plastic bags were placed over the most desirable trees and secured by staples. The various chemicals were then applied by back pack mist blowers.

Several problems were immediately identified. The mist blowers were cumbersome and had a capacity for only 10 minutes of operation - good for about 1/6 acre. Consequently a large support crew was required to ferry chemicals to the mist blowers. On some plots the plastic bags were left on too long (7-10 days) and the seedlings died. Variable winds caused problems with drift of the spray particles and rain showers often occurred within 1-2 hours of spraying, reducing maximum effectiveness.

The results of the chemical tests, in terms of stocking control, were inconclusive. A stage II survey in the fall of 1966 yielded the results shown in Table 2. These data were considered inconclusive for the ester and amine forms of 2,4-D and the Amitrole-T since these chemicals were expected to cause further mortality through the following spring. Silvisar 410 and Paraquat were eliminated as possibilities since, as fast acting killers, any mortality should have been detected by the inspection date. SD-11831 did not appear to affect any of the vegetation. The study

TABLE 2

Inspection Results of 1966 Chemical Tests

	Excess Trees			Crop Trees (Capped)		
Chemical	%Undamaged	%Damaged	%Kill	%Undamaged	%Damaged	%Kill
2,4-D ester	17	51	32	0	70	30
2,4-D amine	50	49	1	100	0	0
Silvisar 510	0	100	0	100	0	0
Amitrole-T	0	100	0	100	0	0
Paraquat	5	95	0	100	0	0
SD-11831	100	0	0	100	0	0

recommended further testing of different quantities and forms of 2,4-D ester, use of paper bags instead of plastic, and hose lines from storage tanks to replace hand carried chemicals. Helicopter application was mentioned as a possible replacement for backpack mistblowers. The most successful aspect of the study was the cost per acre, which, despite the difficulties, totaled $32 per acre.

The study was continued in 1967 in the same area of the Rye Creek drainage. Several new chemicals were included, along with the most promising ones from the 1966 tests. Paper bags were used to cap the best seedlings at about a 12' x 12' spacing. Helicopter application was also tested. Spraying took place in June on 153 acres (125 by helicopter). Inspection in the fall of 1967 yielded the results shown in Table 3. The % damage ratings do not include crop trees. The results include re-examinations of the 1966 applications of 2,4-D ester.

Dacamine 4-D was recommended as the best choice on the basis of damage and kill results, the unavailability of the 2,4-D esters and cost and safety factors. An application rate of 4#AE 2,4-D : 2 pints Ortho 2,4-D adjuvant : 8 ¾ gallons of water per acre was recommended.

Helicopter application was recommended on large acreages.

The results of the 1966 and 1967 tests satisfied forest and district personnel as to the feasibility of chemical treatments. The stalled Wright Tree Service contract was amended to allow the application of Dacamine 4-D by backpack mistblower. Chemical treatment was started in the fall of 1967 and the contract was completed during the summer of 1968.

An inspection of the contract area in the fall of 1968 reported a reduction in stocking to 90 percent of optimum (Table 4). Cost was estimated to be about $45 per acre for the chemical operations. The district forester at that time estimated that this cost could be reduced to $25 per acre through the elimination of inefficiency in the bagging, debagging, and spraying operations.

An additional 200 acres were treated by helicopter in 1968. I could find no post treatment inspection results for these acres. A memorandum in 1969, however, presented a cost breakdown indicating a per acre cost of $29.48.

By the end of 1968, more than 1100 acres had been treated, mostly with Dacamine 4-D. On the basis of this experience, Darby and Sula district personnel, in a May 1969 Multiple Use Survey Report, stated the intent of the Forest Service to pursue a multi-year project to reduce stocking, via chemical means, on some 18,000 acres in the Sleeping Child Burn. Yearly addendums, in the form of Action Plans, were to be used to cover specific projects.

The action plans prepared in the early spring of 1969 by the Darby and Sula ranger districts proposed to aerially treat 1100 acres on each

Table 3

Inspection Results of 1967 Chemical Tests

Spray Date	Insp. Date (Fall)	Chemical and Mix	Application Method	* % Damage Rating: No Damage 0	Damaged 1	Damaged 2	Damaged 3	Damaged 4	Kill 5
1966	1966	2,4-D ESTER 3.34 1 gal: 8 oz.spdr:34 gal.water	Mistblower	17.00	** 51.00				32.00
--	1967	---	---	1.27	14.00				84.33
1967	1967	BANUEL-D 1 pt:1 pt.Adj. to 9 3/4 gal.water	Mistblower	0.4	0		97.2		2.4
1967	1967	PARAQUAT 3 pts:2pts. Adj. to 12 3/4 gal. water	Mistblower	3.6	1.4				95.0
1967	1967	PARAQUAT 1 1/2 pt: 1 1/2 pt.Adj. to 9 3/4 gal.water	Mistblower	1.7	0		0.5	0	97.8
1967	1967	PARAQUAT 4 pts:4 pts Adj. to 9 gal. water	Mistblower	3.6	0		1.4	0	95.0
1967	1967	2,4-D ESTER LV6L 2#AE: 2 1/2 pts.Adj. to 14-1/2 gal. water	Mistblower	2.8	73.6				23.6
1967	1967	DACAMINE 4-D qts:2 qts.Adj. to 8 1/2 gal. water	Mistblower	2.1	42.6				55.2
1967	1967	DACAMINE 4-D 5 qts: 1 3/4 gal. Ad. to 17 gal. water	Mistblower	1.8	67.6				30.7
1967	1967	DACAMINE 4-D 6 qts:2 gal. Adj. to 16 1/2 * gal. water.	Mistblower	5.8	46.1				48.1
1967	1967	DACAMINE 4-D 7 qts: 7 qts. Adj. to 16 1/2 gal. water.	Mistblower	0.5	5.3				94.2
1967	1967	DACAMINE 4-D 8 qts. 8 qts. Adj. to 16 gal. water	Mistblower	0	40.0				60.0
1967	1967	2,4-D ESTER LV6L 4#AE 1/3 gal. Adj. to 9 gal. water	Helicopter (no bags)	3.0	40.2				56.8
1967	1967	DACAMINE 4-D 2# AE: 1# Dagagin:28 1/2 gal. water	Helicopter (no bags)	23.7	64.5				11.8
1967	1967	DACAMINE 4-D 4# AE: 1 1/2 galAdj. to 7.5 gal. water	Helicopter (no bags)	3.1	95.5				0.9

* Ref. H602470-106

** Damage rating codes 1,2,3, and 4 are combined where possible to indicate total percent damaged. The 1967 project results will change in these categories on the final inspection in 1968 as did the 1966 results in 1967. These results, as shown above, are not conclusive at this time.

TABLE 4

Inspection Results of 1968

Wright Tree Service Contract

Stand No.	Acres	Stocking (Trees/acre) Original	Thinned
94.4 - 15	81	2,210	180
94.4 - 16	28	1,590	230
94.4 - 17	49	10,380	2,630
95.9 - 01	66	6,500	260
95.9 - 03	75	5,460	220
95.9 - 04	37	7,060	360
95.9 - 05	36	6,790	120
95.9 - 06	44	3,060	*
95.9 - 08	130	2,375	*
95.9 - 13	100	5,334	*
	651		

*No visual examination made. Visual observation indicated thinned stocking at approximately 300 trees/acre.

district with Dacamine 4-D. Application rate and concentration were increased in the 1969 treatments in an effort to increase the kill of excess trees. A 20 gallon emulsion consisting of 6# A.E. Dacamine 4-D : 1 qt. adjuvant : 18¼ gal. water was used. The number of bagged trees was reduced to 200 per acre in the belief that survival of undesirable trees would bring the total stocking to 300 trees per acre. Bagging and de-bagging operations were contracted in an effort to eliminate excess costs associated with the use of Forest Service personnel. Spraying operations were carried out by Force Account crews and a contracted helicopter.

The objectives of the 1969 treatments were accompanied by a more thorough consideration of possible conflict with other users and of possible undesirable non target effects. Efforts were made to fully inform range permitees of the operations and to distribute information detailing the chemical treatments to the general public. Water samples were taken downstream from the project areas prior to, during, and after the spraying in order to monitor any movement of Dacamine 4-D through the system. These samples were sent to the Missoula City-County Health Department and to the Crops Division of the Agricultural Research Service in Denver, Colorado, for chemical analysis.

Of the 2200 acres planned, 1738 acres were completed in the 1969 field season at a cost of $31.78 per acre. No records exist concerning the initial success of these treatments in reducing stocking.

With the 1969 project an apparent success, plans were laid for an equally ambitious operation in 1970. A goal of 2400 acres was set, 1200 on each district. Project plans were virtually identical to those for 1969. A draft of the Multiple Use Survey Report of 1970, however, included a recommendation that more detailed information on the activity of Dacamine 4-D in soil and water be obtained by an independent research organization. This recommendation was apparently in response to a suggestion by Regional Office personnel in December 1969 that there was a need to monitor the chemical applications and evaluate them from an environmental standpoint. The Multiple Use Survey Report was then reviewed by six Divisions and the Multiple Use Coordination-Area Studies Group. This intensive review identified two areas of concern: (1) the side effects of Dacamine 4-D were not adequately known and might have adverse effects on fisheries and wildlife, and (2) the degree of public involvement prior to implementation of the plan was insufficient. The fear was expressed that "we again will be attempting to gain public and other agency understanding and cooperation after we have designed, approved and set in motion a controversial type of project." (Neal Rahm, Regional Forester). A year's delay in the project was recommended so that answers to environmental questions and the desired level of public involvement could be obtained. A revised proposal was prepared by district personnel in January of 1971 but was not approved. No chemical treatments have been applied since that time.

Faced with the elimination of Dacamine 4-D as a management tool, the Forest Service re-examined mechanical methods. In a 1970 study[1] on the Darby and Sula districts a variety of mechanical methods were applied and then evaluated with respect to cost and success in reducing total stocking. Methods included in this study were: (1) hand pulling, (2) snipping with heavy duty lopping shears, (3) circle snipping - a variation of (2) wherein a 5 foot circle was cleared around designated crop trees located on a 15' x 15' spacing, (4) weed cutter, and (5) brush cutter circular saw. The results of this study are shown in Table 5. In general, the mechanical methods were considered too costly. In addition, the inability to eliminate live limbs on severed stumps was noted, especially with respect to the weed cutter and circular saw methods. The study recommended that no mechanical treatments be applied at that time but that the methods be re-evaluated in 4-6 years. After such a time interval the authors felt that small seedlings would be more visible and crown recession due to shading of lower branches would

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[1]Richard Lord, "Cost Study to Determine Mechanical Alternatives to Chemical Thinning," Sula Ranger District, June 1970.

Table

Cost Comparison of Thinning Methods

Method	Acres	1/ Cost/Ac.	T/A Before	T/A After	% Removed	3/Cost/ Removed Tree
1. Sula Hand Pulling	8.0	$114.57	6360	480	92.4	.019
2. Sula Snipping	7.6	85.04	8610	510	94.1	.015
3. Sula Circle Snipping	2.0	45.07	9320	5760	38.2	.013
4. Darby Hand Pulling	0.2	76.07	15,000	300	98.0	.006
5. Darby Snipping	0.1	97.00	15,000	500	96.7	.007
6. Darby Weed Cutter	0.1	101.20	15,000	250	98.3	.003
7. Darby Brushcutter Circle Saw						
Small Material (6 to 18 inches)	0.3	35.20	15,000	500	96.7	.008
Large Material (12 to 30 inches)	0.2	19.80	10,000	300	97.0	.002
Average	0.5	29.00	13,000	420	96.8	.003
8* Wright Tree Service (Chem. Mistblow.	651.0	37.36	5580	2/541	90.3	.007
9. 1969 Helicopter (Chemical)	173.8	26.66	7450	2/790	89.4	.004

1/ Cost per acre figures are cost of doing the work only and do not reflect transportation, equipment and maintenance, and indirect (overhead) costs. Sula circle snipping and all of the methods are based on less than a full continuous days operation and therefore do not reflect the true fatigue factor.

2/ Stocking levels on chemically thinned areas are as of fall 1969. Some additional mortality is expected and visual observation has revealed some resprouting of chemically treated trees.

3/ This column is an index of the relative efficiency of a method. Generally a low value indicated a more efficient method.

* Wright Tree Service - The cost shown is based on contract rate. First attempt was using hand pull method later modified to sacking selected trees and their spraying with chemical. The cost per acre is not an actual cost. The company experienced much higher cost than what is shown. Perhaps as high as $60.00/acre.

reduce the lower live limb problem.

Thermal thinning was briefly considered. An apparatus designed to force hot air (550^{o} F) over the foliage at a distance of 3 feet was tested in August 1972. Results were termed "uncertain" in September and "successful and promising" in December. Plans were made to treat 200 acres with this apparatus in 1974, but to my knowledge the project was never carried out. Rugged terrain, downfall and the necessity of a truck to carry the thermal unit certainly limited widespread use of this method.

In 1974, the decision was made to resume large scale stocking control efforts in the 14,000 acres identified as in need of treatment. Mechanical methods were to be used. As stated in the EAR prepared in 1974, the objectives of the proposed activities were:

(1) to secure growth potential on suitable sites and redistribute growth to selected stems in order to provide a variety of usable wood products,

(2) to maintain a full spectrum of resource management opportunities in the area,

(3) to obtain much needed information on the management of immature lodgepole pine in this locale, particularly its response to the methods and spacings proposed for use,

(4) to provide employment opportunities for a number of people, most of whom will probably be local.

Treatments proposed included: uniform thinnings of 7' x 7', 10' x 10', and 12' x 12' spacings, dominant tree and crop tree techniques. The uniform spacings were to be used on the best sites where the higher cost of wide uniform spacings would be justified by increased growth. In areas where wildlife and/or esthetics were top priority a modified crop tree technique was planned. This treatment consists of removing all stems within a 10 foot radius of a designated crop tree. Fifty to 100 crop trees per acre are chosen using a grid technique of fixed distance between trees. Since the number of stems removed is much less with this model, the cost per acre is reduced. The crop tree system was recommended for stands on poorer sites. On sites where dominance of a few trees was being expressed it was planned to employ a dominant tree selection method. Those trees expressing dominance are retained and all other stems cut. A variable spacing of 2-9 feet between trees was anticipated. The resulting stand would produce a natural effect which combined increased desirable growth and an intermediate cost per acre.

Stands were chosen for treatment on the basis of current tree height, site index as estimated from snags in the area and habitat type. Thinning units were located so as to provide escape cover for big game and to insure an adequate discontinuity of fuel.

In general the best sites are located on the Sula district, the poorer ones on the Darby district. The uniform spacings, designed primarily for timber objectives, have been used primarily on the Sula district, while the crop tree or circle thinning treatments have been applied mostly to stands on the Darby district.

The magnitude of the effort necessary to reduce the stocking of a stand from the 10s of thousands to a few hundred stems per acre by mechanical means is considerable. Cole (1973) stated that hand thinning is usually too costly and physically overwhelming. The characteristics of the stands in 1974 gave every indication of support to his evaluation.

The average dominant height was around six feet, large numbers of small trees, < 12" high, were present and live limbs at or near ground level were present on most stems in most stands. Observation of the 1970 test of mechanical methods indicated that limbs left on cut stumps and missed seedlings responded to the increased growing space. It was therefore considered imperative to minimize the number of seedlings and lower live limbs (LLL) in the residual. The experience with mechanical methods in 1965 and 1970 indicated the impossibility of removal of all LLL's and small seedlings. The problem, therefore, was to specify some number of these stems that could be left which would allow silvicultural objectives with respect to stocking control to be met but also insure a reasonable cost per acre.

The first contracts let on the Sula ranger district in 1974 specified a 7' x 7' uniform spacing for leave trees, removal of all limbs from cut stumps and removal of all other stems over 12" tall. The work bogged down almost immediately due to excessive numbers of LLL's found in inspections. Eventually the contract was amended to allow LLL's to be left on stumps less than 2" in height and the contract was completed. However, the large numbers of small trees and LLL's put the total stocking well above that desired. The following year the minimum height specification was dropped. A desired stocking level for leave trees was specified with a 20% deviation allowed. The 20% included seedlings and LLL's. For a specified spacing of 12' x 12' (303 trees per acre) a range of 243-363 stems per acre was acceptable. Thus for inspection purposes, and hence payment, all live lodgepole pine stems were weighted equally. Recognition of this led to a tendency for contractors to increase the spacing of leave trees to counter balance the effect of seedlings and LLL's. On some of the 1975 contracts and in 1976, the categories of the residual were separated in order to gain more control over the stocking of leave trees. A range for crop trees was specified with penalties of up to 20¢ per tree provided for over cutting, and re-work orders under threat of default for undercutting. Excess trees and LLL's were counted separately. Different upper limits were specified on different contracts. Rework orders under threat of default were used to force compliance. The latest contract considered in this study (1977) specified a 10% deviation in leave tree stocking from the desired level of 436 stems per acre, a maximum of 200 LLL's and 150 excess trees, for a total maximum stocking of 830 stems per acre.

Compliance with contract specifications was determined on the basis of a systematic sampling procedure. On blocks less than 20 acres, 4-1/300 acre circular plots per acre were taken. On blocks greater than 21 acres, 3 - 1/300 acre plots per acre were taken. The components of the residual were tallied when the main stems intersected a horizontal circle 6.82 feet in radius. Per acre estimates for each component were computed by the formula:

$$\text{stems/acre} = \frac{(\text{total number in sample}) \times 300}{\text{number of plots}}$$

With few exceptions, contractors had difficulty meeting contract specifications. Small trees and LLL's in excess of allowable levels continually required reworking of an area. The greatest difficulty was experienced in stands which contained a large number of small (< 12") stems. Generally these stems had live limbs at or near ground level and were easily camouflaged by accumulated slash. In many cases contractors insisted on using power saws. The small, whiplike stems were not easily severed, and the reluctance to bring the chain in contact with the ground in order to cut the live limbs resulted in unacceptable numbers of excess trees and LLL's. Best results were obtained in stands that did not have many small stems and were treated by clippers or machetes.

Two sources of labor have been used to carry out the treatments: in service or force account crews, and contract crews. Given the silvicultural objectives as stated in the 1974 EAR my experience with both sources has shown them to be complementary. The objectives required variations in intensity and pattern of treatments in accordance with site quality, timber and non-timber objectives. Generally the contract approach is best suited to uniform spacings in relatively homogeneous stands of fairly large acreages. Contract specifications are necessarily rigid for legal and administrative reasons. A single contract, therefore, cannot contain the flexibility needed to adjust silvicultural treatments to meet major changes in stand characteristics. For example, on several occasions a contract bogged down due to the occurrence of an acre patch of extremely dense, stunted reproduction. A situation was thus created that demanded application of a costly silvicultural treatment despite the fact that it was inappropriate. Force account crews, on the other hand, are not bound so tightly to treatment specifications on every acre. In a similar situation a skilled crew boss could merely delete such an area from treatment. A trained force account crew is most useful in areas where considerable variation in stand structure exists and where it is desirable to vary intensity and pattern of treatments to meet non-timber objectives.

Treatment Evaluation

Description of Residual Classes

Age. Table 6 presents the 1978 sample means and standard deviations for the ages of excess trees occurring in 8 stands treated in the period 1967-1976. The distribution of 2 year age classes, expressed as a percent of total sampled, for each stand and for all stands combined is given in Figure 2. Note that the stands treated with a dominant tree technique are not included. This is due to a lack of stems in the excess tree class found during sampling.

TABLE 6

Mean Age of Excess Trees - 1978

Stand I.D.	n	$\overline{X}$	s	c.v.
1467	11	9.2	1.7	.19
2170	25	10.6	2.2	.21
1174	46	10.1	2.5	.24
2174	33	9.8	2.9	.29
4274	12	9.1	2.3	.25
1375	13	10.5	2.6	.25
1276	7	9.3	1.1	.12
2176	50	9.4	2.6	.27

Table 6 shows a common mean age of approximately 10 years for excess trees encountered in the 8 stands sampled. This indicates that the stems missed during the various treatments are of the same generation. That is, those stems missed in a 1970 treatment when they were 2-3 years old were missed in a 1976 treatment when they were 7-8 years old. This

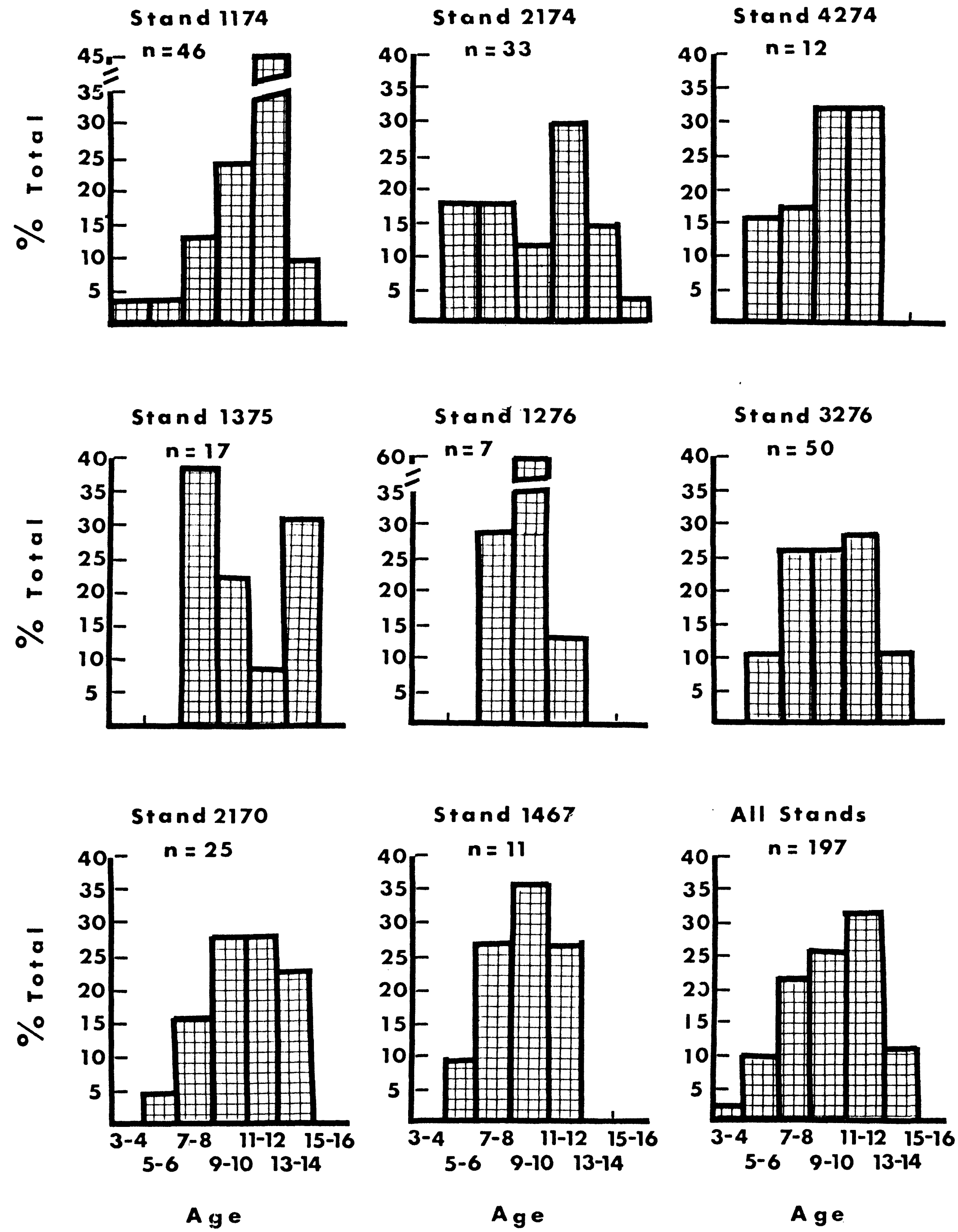

Figure 2

Distributions of Two Year Age Classes for Excess Trees by Stand suggests that the class of stems providing the source of excess trees has moved into successively higher age classes and that continued ingrowth into the lower age classes has not occurred. If such ingrowth had occurred one would expect the mean 1978 age of excess trees to be less in stands treated in 1976 than in stands treated in 1970 or 1974. Since stems are missed during treatment as a function of their visibility through accumulated slash and other vegetation, the greater depth of slash in older stands would provide a proportionately greater number of young stems in the excess tree category.

Figure 2 shows the 1978 composition of the excess tree category by 2 year age classes for each stand and for all stands combined. With the exception of stand 1375, the shape of the distribution is similar in all 8 stands. The most frequently encountered stems are in the 7-12 year old range. Roughly 80-90% of the stems are between 5-12 years old. In only one stand, 1174, were stems less than 5 years old observed. Evidently regeneration had ceased by 1974.

These results suggest that the source of the excess tree problem, in the stands sampled, are stems originating in about a 7 year period beginning some 5 years following the burn. The significance of this is especially evident in stand 1467. At time of treatment at least 70% of the stems termed "excess trees" in 1978 were not present. No matter how successful the treatment was in 1967, continued regeneration doomed the treatment to failure in 1978. A similar situation is evident in stand 2170 where at least 20% of the excess trees originated after treatment. In contrast, with only one exception, no stands treated in 1974 or later contain excess trees which originated after treatment.

The work of Critchfield (1957), Lyon (1976) and Lotan (1973) indicated that the release of seed from serotinous cones following breakage of the resin bonds by fire is generally complete within 1 or 2 years. Lyon reported seedling establishment on the Sleeping Child burn complete after 2 years. The seed source for most of the excess trees found in 1978 may be from one of the following. First, windblown seed from non-serotinous cones on trees in adjacent unburned stands. This possibility seems unlikely since most of the stands sampled were beyond the 200-300 foot range of windblown lodgepole pine seed (Critchfield 1957). Second, seed from non-serotinous cones born on sexually mature trees in the fire established stands. Since lodgepole pine reaches sexual maturity at a relatively early age, 5-10 years (Lotan 1973), it is conceivable that seedlings established in 1961 could have begun seed production by 1966. A third possibility is that some serotinous cones survived the 1961 fire with resin bonds intact. Subsequent deterioration of the parent tree then provided a periodic addition of serotinous cones to the forest floor. The resin bonds of these cones were then broken by summer surface temperatures (Crossly 1956, Lotan 1964) and viable seed released.

The apparent cessation of regeneration indicated by the paucity of 3-6 year old excess trees in the sample stands shown in Figure 2 is probably the result of unfavorable germination and growth conditions created by closure of the canopy prior to treatment, rather than a termination of seed source. The infrequent occurrence of excess trees older than 11-12 years merely reflects the fact that older (taller) stems are less likely to missed during treatment.

Table 7 gives the sample means and standard deviations of the ages of cut stumps supporting LLL's on six stands treated from 1970-1976. Chemically treated stands are not included since LLL's occur only in mechanically treated stands. No results are given for stands treated with the dominant tree technique since no LLL's were found in these stands during sampling.

TABLE 7

Mean Age of Stumps Supporting LLL's

Stand I.D.	n	X	s	c.v.
2170	29	7.5	1.5	.20
1174	35	6.9	1.4	.21
2174	16	8.1	1.9	.24
4274	3	7.7	1.5	.20
1276	4	9.7	1.7	.18
3276	21	8.5	2.3	.27

Figure 3 gives the distribution of 2 year age classes expressed as a percent of the total sampled, by year of entry and for all years combined.

Table 7 shows that LLL's surviving until 1978 occurred on stumps averaging about 8 years of age. Figure 3 shows that 90% of the LLL's surviving in 1978 occurred on stumps between 5 and 10 years old regardless of the age of the stand at time of treatment.

Since no data exist as to the distribution of LLL's on the various age classes of stumps immediately following treatment, no survival probabilities with respect to stump age can be made. A plausible explanation of the results based on treatment techniques is offered instead.

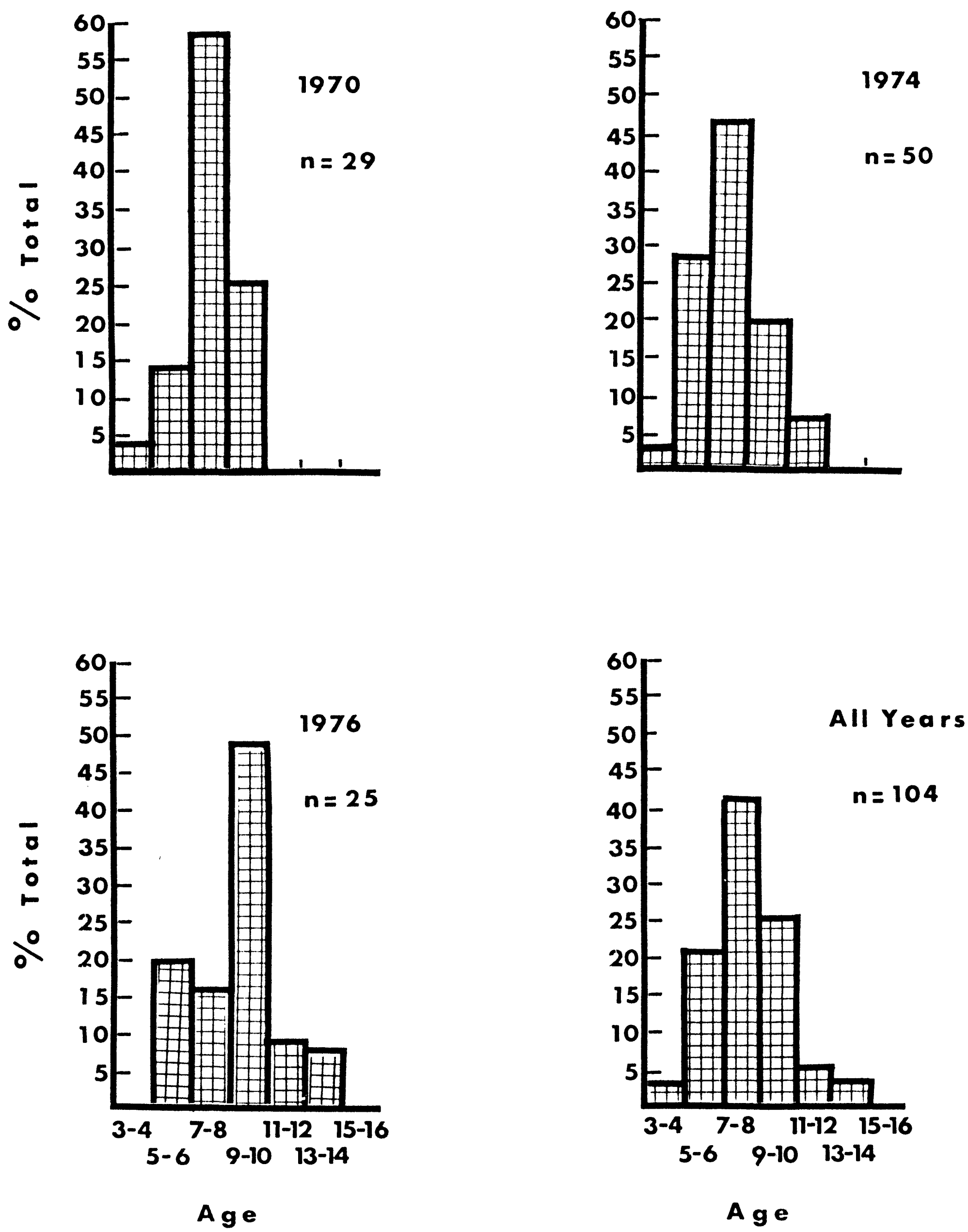

Figure 3

Distributions of Two Year Age Classes

for LLLs by Year of Treatment

A LLL occurs when an attempt is made to sever a stem and a lateral is left on the stump. Treatment specifications allowed a maximum stump height of 8 inches in an effort to reduce the probability of leaving a live lateral on the stump. The use of clippers, machetes, and hatchets, the most commonly used tools, tended to leave stumps considerably less than 8 inches high. Two factors cause LLL's. First the stem must be tall enough to attract attention through competing vegetation and slash from previously cut stems, and second, the lateral must exist near ground level in order to be left on the stump. The first factor implies a minimum height for stems to be possible sources of LLL's. Below this height the attempt to cut will not be made and the stem becomes an excess tree. The second factor implies a crown extending to near ground level. Older stems on which the crown has receeded several inches from ground level would be less likely to support a lateral following cutting. The distribution shown in Figure 3, then, can be interpreted as follows. Stems less than 5 years old were not cut, therefore, no LLL's left; on stems older than 10 years the cutting method, combined with some crown recession, precluded LLL occurrence.

Given the above explanation of LLL occurrence, the magnitude of the LLL problem depends on the number of stems in this age range at time of treatment.

Initial height. Table 8 gives the means, standard deviations and coefficients of variation for the height of each component class at time of treatment for the 13 stands sampled. The chemically treated stands (1467 and 2467) have no estimates for excess trees due to difficulty in counting back a sufficient number of whorls. However, the age data for excess stems in these stands indicate that most of these stems originated after treatment.

TABLE 8

Mean Component Class Heights (cm)

at Time of Treatment

Stand	Leave				Excess				LLL			
	n	$\bar{X}$	s	c.v.	n	$\bar{X}$	s	c.v.	n	$\bar{X}$	s	c.v.
1467	11	42	.08	.18		--				--		
2467	12	36	.12	.35		--				--		
2170		68				4				10		
1174	36	184	39	.21	44	29	14	.48	35	18	11	.61
2174	30	167	69	.41	31	31	14	.47	16	29	11	.36
3574	26	187	57	.30	10	32	15	.46	3	27	21	.78
4274	6	242	42	.17	12	25	14	.56	3	11	12	1.05
3274	15	250	55	.22	6	40	18	.45		--		
5574	14	271	53	.20		--				--		
1375	11	225	84	.37	12	26	14	.53	1	19	--	--
1276	16	219	42	.19	7	25	6	.24	4	18	9	.49
3276	37	257	55	.22	50	36	17	.48	25	24	13	.52
2276	2	295	21	.07	3	33	23	.70	2	20	13	.64

(1) Leave Trees. The stands in table 8 are ordered by year of treatment. Mean height at treatment ranged from less than ½ meter in stands treated in 1967 to over 2½ meters in stands treated in 1976. The variability in initial height can be seen in the stands treated in 1974. Stands in the PSME series generally contained taller trees than those in the ABLA series. In the PSME series the greatest initial heights were on a PSME/SYAL h.t., the smallest on a PSME/VAGL h.t. In the ABLA

series, the ABLA/MEFE h.t. supported leave trees of greater initial height than those on an ABLA/XETE h.t.

The ordering of stands within either of the series is in agreement with the order of yield capability classes for those series and habitat types as found by Pfister et al. (1977). However, in Pfister's work the ABLA/MEFE and ABLA/XETE habitat types had higher productivity ratings than the PSME/SYAL, PSME/CARU or PSME/VAGL habitat types. To the extent that early height growth is an important indicator of site productivity, then, our results conflict.

(2) Excess trees. The initial mean height of the excess tree class ranged from 4 cm in a stand treated in 1970 (stand #2170) to 40 cm in a stnad treated in 1974 (stand #3274). There was considerable within stand variability as indicated by the relatively large coefficients of variation. This variability may be due largely to the variation in age found for the class.

There does not appear to be a strong relationship between stand age and initial heights of excess trees. The mean heights of excess trees in stands treated in 1974 and 1976 were 31.3 and 31.4 cm, respectively, despite a two-year age difference. The very small initial heights of excess trees in stand 2170 probably reflects the continued establishment of seedlings past the date of treatment.

There does not appear to be any relationship between initial height and habitat type. The smallest mean, 25 cm, was found in the stand that contained the second tallest leave trees (stand #4274). The mean initial excess tree heights for stands in the ABLA and PSME series were 29 cm and 30 cm, respectively, a difference of only 1 cm. Within the ABLA series there was a difference between the MEFE and XETE types of only 2 cm, and the direction of the difference was the reverse of that for leave trees. Within in PSME series the variability between types was greater, but the large coefficient of variation and the non-correspondence to leave tree height suggest that important differences (say 5 cm) would not be detectable and even if they were it is doubtful the difference could be ascribed to change in habitat type.

Excess trees are created primarily as a function of their invisibility through accumulated slash. The height of a seedling in relation to slash density, continuity, and depth determines in large part, its invisibility. The number of stems/acre cut and the dimensions of the cut trees influence these slash characteristics. The interaction of these factors plus the variability in thinner's thoroughness have undoubtedly been of greater significance in determining the height of missed trees than has a 2 year age difference or the variation in site quality sampled.

The similarity in mean height between the 1974 and 1976 treatments may be the result of a tendency to miss the more stunted individuals in an age class in the '76' treatments. More vigorous stems, with a greater height growth, are less likely to be missed.

(3) LLL's. The mean heights for LLL's in table 8 include the length of the upturned lateral plus the height of the stump at point of attachment. The variability about these means is at least partially attributable to variation in the height of the point of attachment. The age of the stem on which the lateral is left also contributes to the variation. Small stems have shorter laterals than large

stems. The range in age of stems in a given stand therefore offers a corresponding range of lateral lengths available for LLL status.

The mean initial heights range from 10 cm in stand 2170 to 29 cm in stand 2174. The variability in initial mean height among the stands does not appear to be related to stand age. The initial mean heights for LLL's in stands treated in 1976 are very close to those heights for LLL's in stands treated in 1974, and, though LLL's in the stand treated in 1970 had the smallest initial height, at least one stand, 4274, treated in 1974, had LLL's of similar initial height.

Figure 4 shows the relative frequency distributions of 5 cm height classes for LLL's on three stands and for all stands combined. All four distributions are basically bell shaped. The common shape may be explained by two factors: (1) the larger height classes (longer initial laterals) are more easily seen and therefore eliminated during treatment, and (2) the smaller classes either do not exist in significant numbers and/or the smaller laterals and buds lack sufficient vigor to successfully turn up and function as vertical stems.

Stands 1174 and 2174 were treated by the same contractor, under specifications which allowed all LLL's on stumps less than 2" in height to be left. Post treatment inspections during 8/74 calculated 669 LLL's and 2375 LLL's left in the general vicinity of stands 1174 and 2174 respectively. An inspection during 9/78, using the same procedure, found 150 and 533 LLL's on these stands for an estimated survival rate of approximately 23% for each stand.

Assuming the stump heights in both stands had a similar distribution, it appears from Figure 4 that the surviving LLL's in stand 2174 had a

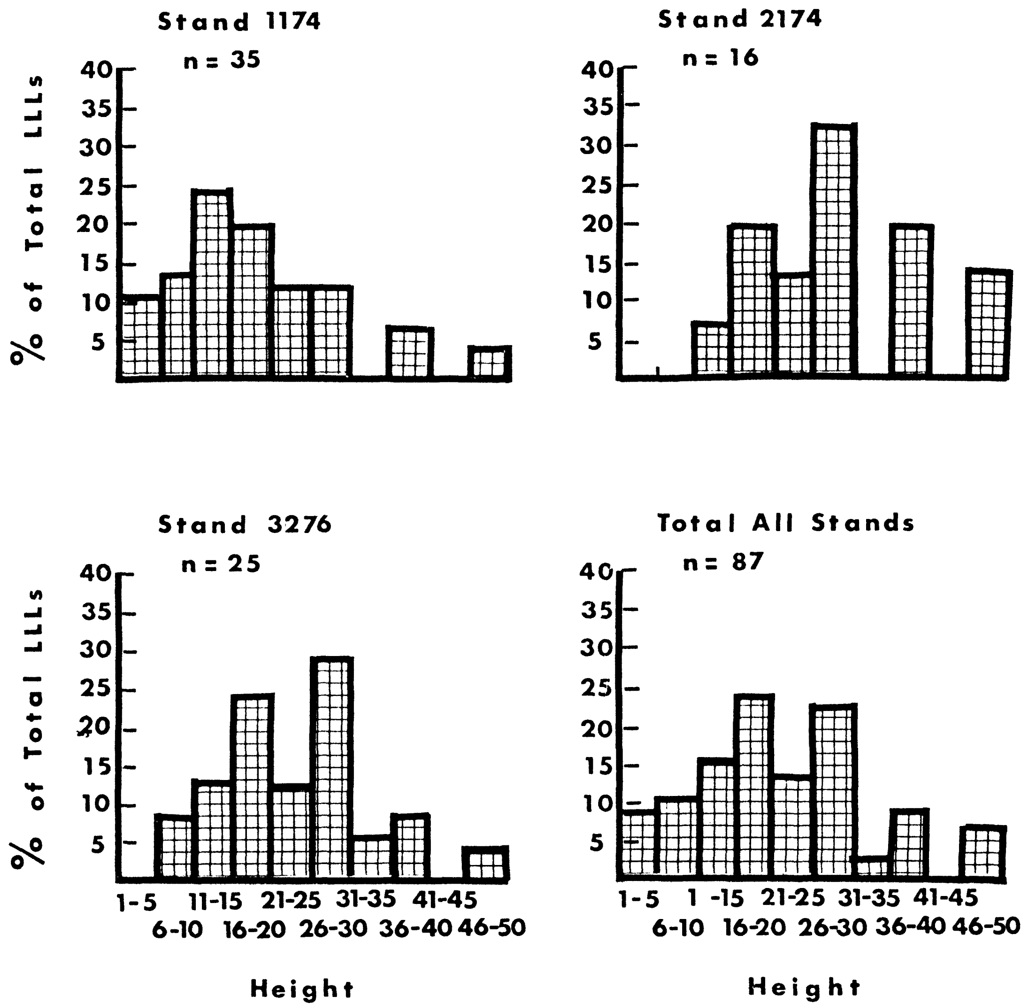

Figure 4

Distributions of 5 cm. Height Classes

for Initial LLL Heights (cm)

greater initial length than those in stand 1174. 100% of the LLL's found in stand 2174 had initial heights greater than 10 cm initially. I suspect that characteristics of the understory vegetation are primarily responsible for this contrast. Stand 2174, on an ABLA/XETE h.t., has a thick cover of beargrass (Xerophyllum tenax) which likely caused early mortality of the lowest live limbs. By 1974 the live limbs left on stumps were the larger, more vigorous laterals. Stand 1174, on an ABLA/MEFE h.t., still had a fairly sparse undergrowth in 1974. The lowest live limbs on stems in this stand were therefore not shaded out, and a proportionately greater number of smaller laterals were left.

In stand 2174, 62% of the surviving LLL's were greater than 26 cm in height at treatment. In stand 1174, only 20% of the LLL's were greater than 26 cm in height at treatment. Since the ABLA/MEFE h.t. generally supports larger trees one might expect the reverse situation. However, the effect of #stems/acre on the visibility of LLL's may have masked this trend. Stand 1174 had an initial density of about 5000 stems/acre while stand 2174 had an initial density of over 20,000 stems per acre. The greater slash depth and continuity in stand 2174 provided the camouflage necessary to hide large laterals from view.

The distribution for stand 3276 is similar to that for stand 2174 though it includes the 6-10 cm height class missing in the latter. This stand, on a PSME/VAGL h.t. was thinned in 1976. Initial density was approximately 5200 stems/acre. Contract specifications allowed a maximum of 200 LLL's per acre. An inspection during 9/78 estimated 160 LLL's per acre. No reliable estimate of mortality can be made, however, since the contract inspection results of 1976 were an average over some 80 acres while stand 3276 contained only about 5 acres. The moderate stocking in this stand and the absence of a dense understory is the most likely reason for the paucity of LLL's in the greater height classes.

The distribution of height classes for all LLL's encountered in the 1974, 74, and 76 treatments is shown in Figure 4. Over all mechanical treatments and habitat types sampled 83% of the surviving LLL's had initial stump and lateral heights greater than 10 cm. If an average of 5 cm is taken as the height from ground level to point of attachment a 5 cm lateral remains. During my tenure in the Sleeping Child Burn great concern was expressed that anything green left on a severed stump would produce a LLL. These results indicate that such is not always the case.

1977 height. Table 9 gives the means, standard deviations, and coefficients of variation for the height of each component class in 1977. The year 1977 is used as a marker of post treatment conditions because the 1978 measurements were made only in those stands sampled after elongation had ceased. That is, the most complete data base consists of 1977 measurements which were made in all stands.

(1) Leave trees. Mean leave trees height in the 13 stands sampled varied from 1.6 to 3.5 meters. Stand 2170 was severely damaged by a hailstorm in 1974, hence the below average height.

TABLE 9

Mean Component Class Heights (cm) 1977

Stand	Leave				Excess				LLL			
	n	$\overline{X}$	s	c.v.	n	$\overline{X}$	s	c.v.	n	$\overline{X}$	s	c.v.
1467	11	263	29	.11	12	110	42	.39		--		
2467	12	248	40	.15	12	109	27	.25		--		
2170	20	160	24	.16	25	46	16	.35	29	41	11	.27
1174	36	269	51	.19	46	47	18	.38	35	37	12	.34
2174	30	257	85	.33	33	60	24	.40	17	50	11	.22
3574	26	268	61	.23	10	54	19	.36	3	43	23	.53
4274	6	337	45	.13	12	44	17	.39	3	29	14	.50
3274	15	336	72	.21	6	62	17	.28		--		
5574	14	351	65	.18		--				--		
1375	11	296	96	.32	12	35	17	.47	1	25	--	--
1276	16	257	48	.19	7	31	6	.19	4	21	9	.42
3276	37	294	57	.20	50	42	19	.45	25	29	14	.48
2276	2	330	28	.09	3	41	26	.62	2	23	11	.49

When the stand means are grouped by habitat type, weighted by the sample size, and averaged, the ordering in Table 10 is obtained.

TABLE 10

Mean 1977 Height of Leave Trees

by Habitat Type

Habitat type	No. Stems	No. Stands	Mean Height (meters)
ABLA/XETE	44	3	2.6
ABLA/MEFE	74	4	2.7
PSME/VAGL	78	3	3.0
PSME/CARU	6	1	3.4
PSME/SYAL	14	1	3.5

As with initial conditions, the greatest heights are found in the PSME series. This result is at odds with the productivity ratings of Pfister (1977-Forest Habitat Types of Montana) which puts the ABLA series generally above the PSME series. Within each series, however, the direction of differences between types is in agreement with the ratings.

When the coefficients of variation are compared between initial and 1977 conditions it is evident that the variability has decreased since treatment. This may be due to a height growth response of those stems which were experiencing some deliterious effects of competition in the unthinned condition.

(2) Excess trees. Excess tree mean heights in the 13 stands ranged from 31 cm in stand 1276 to 110 cm in stand 1467. In the stands treated mechanically since 1970 the range is much less, from 31 to 62 cm. The mean heights of excess trees in the mechanically treated stands is somewhat less in stands treated in 1976 than in stands treated in 1974. The weighted average of the mean heights in the 1974 stands is 54 cm while that in the 1976 stands is 32 cm. Since the mean 1978 age of the excess trees is similar in both categories (Table 5), the difference in height may be due to the length of time spent in the thinned condition. Those excess trees left in 1974 experienced 3 years of relatively competition free growth while those left in 1976 had only 1 year prior to measurement. In addition, those stems missed in 1976 are likely the more suppressed individuals of the age class, witness their similar initial height to those left in 1974 despite being 2 years older, and have not responded to decreased competition in a single growing season.

As with the leave trees, a decrease in the coefficient of variation is noticed since time of treatment. The response of individuals experiencing overcrowding to the increased growing space is thought to be the cause of the decrease. Such a response would reduce the disparity in height between individuals under stress and those in a more open condition.

(3) LLL. As a class, the upturned laterals in 1977 were of a comparable mean height to the excess trees. Over the stands sampled the mean height ranged from a low of 21 cm in stand 1276 to a high of 50 cm in stand 2174. Generally, the stands treated in 1974 have a greater mean LLL height than the stands treated in 1976. The average mean LLL height was 40 cm in the 1974 stands and 24 cm in the 1976 stands. These numbers are in agreement with general impressions during sampling that the LLL heights in the most recent thinnings were somewhat less than in the earlier ones. A partial explanation is that the most recent LLL's had existed as a vertical stem for only a single growing season and hence most of the total height in 1977 was due to growth as a lateral. Also, the 2 year time difference may have reduced the potential of the lateral to perform strongly as a vertical stem.

As with the other component classes, the coefficient of variation dropped under that calculated for time of treatment.

Height growth. The mean annual height growth for each component of the residual for the years 1974 to 1978 is given in Table 11 for each stand sampled. Missing values are primarily due to insufficient sampling time. For those stands where sampling was done prior to completion of leader elongation the 1978 growth rates are not available. In stand 5574, treated with a dominant tree selection method no excess

Table 11

Mean Height Growth (cm.) of Component Classes
X(m,s)*

Stand	CC	74	75	76	77	78
1174	1	28(28,11)	24(36,8)	28(36,8)	33(36,8)	36(8,5)
	2	6(18,3)	5(44,2)	6(46,2)	8(46,4)	10(20,5)
	3	5(15,2)	6(35,2)	6(35,2)	8(35,3)	11(6,4)
1276	1	--	34(16,13)	36(16,10)	38(16,9)	36(16,10)
	2	--	--	6(7,2)	6(7,2)	7(7,3)
	3	--	--	--	3(4,1)	10(4,1)
1375	1	26(11,9)	29(11,8)	35(11,10)	35(11,14)	--
	2	5(12,2)	5(12,2)	5(12,2)	4(12,2)	--
	3	--	4(1,-)	2(1,-)	4(1,-)	--
1467	1	29(11,7)	35(11,13)	35(11,8)	39(11,5)	46(11,8)
	2	15(12,7)	18(12,8)	19(12,8)	24(12,9)	27(12,9)
2170	1	14(20,6)	14(16,5)	13(17,5)	21(20,7)	19(20,6)
	2		5(25,3)	6(25,3)	9(25,4)	9(25,5)
	3	5(7,1)	6(28,2)	6(29,3)	10(29,6)	11(28,5)
2174	1	28(22,12)	24(30,10)	29(30,9)	36(30,10)	33(8,7)
	2	5(16,2)	7(31,4)	11(33,6)	13(33,7)	16(15,7)
	3	6(11,2)	6(16,2)	6(17,3)	9(17,5)	13(5,3)
2467	1	28(12,4)	28(12,6)	34(12,7)	44(12,8)	43(12,11)
	2	12(12,4)	13(12,5)	15(11,7)	26(12,8)	24(12,5)
2276	1	--	30(2,0)	35(2,7)	45(2,7)	35(2,7)
	2	--	8(3,6)	6(3,2)	8(3,3)	10(3,2)
	3	--	6(1,-)	5(2,-)	3(2,-)	10(2,-)
3276	1	--	--	--	38(37,11)	35(37,9)
	2	--	--	--	7(50,5)	10(50,7)
	3	--	--	--	4(25,4)	9(25,4)
3274	1	40(3,10)	27(15,12)	26(15,11)	33(15,11)	26(12,9)
	2	--	10(6,-)	3(6,-)	9(6,-)	5(6,-)
3574	1	--	22(26,8)	28(26,10)	31(26,10)	23(26,8)
	2	--	8(10,-)	7(10,-)	7(10,-)	2(10,-)
	3	--	3(3,-)	7(3,-)	6(3,-)	

Table 11 (cont.)

		74	75	76	77	78
4274	1	27(6,5)	28(6,10)	28(6,4)	38(6,16)	
	2	6(10,2)	5(12,1)	6(12,1)	8(12,3)	
	3	--	3(3,2)	7(3,3)	6(3,1)	
5574	1	28(14,10)	26(14,4)	26(14,6)	27(14,6)	

* Where a '-' appears in place of an estimate of σ, the estimated means are based on an altered measurement procedure and a variance was not calculated.

trees or LLL were encountered and hence no figures are available. The stands are grouped by habitat type to facilitate interpretation of results.

(1) Leave trees. Height growth for leave trees in most stands averaged in the high 20 cm range in 1974. Exceptions are stand 2170 ($\overline{X}$ = 40) which was damaged by hail in 1974 and stand 3274 ($\overline{X}$ = 40) where the small sample (n = 3) may have yielded an unreliable estimate. Excluding these two stands, the mean 1974 height growth differed by only a few centimeters among the 6 stands for which 1974 growth rates were obtained. By 1978 height growth in most stands was in the 35-45 cm range. The greatest growth was found in stands 1467 and 2467 - treated with Dacamine 4-D in 1967. The mean height growth for these stands is some 10 cm greater than for the stands treated in 1974 and after.

There is no clear stratification of height growth in any given year according to habitat type. Table 12 gives the mean 1977 height growth of leave trees by habitat type. With the exception of the PSME/SYAL h.t. only a few centimeters separate the means. The reduced height growth in the PSME/SYAL h.t. is probably a result of an infestation of the sample stand by needle cast fungi in 1975.

TABLE 12

Mean 1977 Leave Tree Height Growth by Habitat Type

Habitat type	No. Stems	No. Stands	Mean 1977 Height Growth (cm)
ABLA/XETE	44	3	38
ABLA/MEFE	74	4	35
PSME/VAGL	78	3	34
PSME/CARU	6	1	38
PSME/SYAL	14	1	26

(2) Excess trees. In most of the sample stands, the excess tree component class averaged around 5-6 cm height growth in 1974. This average increased to around 10 cm in 1978. Substantially greater 1978 height growth was found in the chemically treated stands 1467 and 2467 ($\bar{X}$ = 27 and 25 cm respectively). This is an apparent anomally since the age data show the stems to be of approximately the same age in all stands and such a disparity is unexpected. However, the greater height growth of excess trees in the chemically treated stands may be explained by the evidence indicating that these stems originated after treatment and as such have not grown under the level of competition experienced by excess in stands treated after 1974. Among the mechanically treated stands the least growth was observed in stand 1375, a 12' x 12' uniform spacing on a ABLA/MEFE h.t. The reduced height growth of excess trees in this stand may be due to competition from the mat of pine grass (Calamagrostis rubescens) blanketing the site. The greatest growth was found in stand 2174, a 7' x 7' spacing on an ABLA/MEFE h.t.

(3) LLL's. In those stands where growth rates for both excess and LLL's are available the annual rates are quite similar. Over the 5 year period 1974-78 the mean annual height growth for the LLL class in most stands generally increased from around 5 cm to about 10 cm. For stands treated in 1974, 75 and 76 the comparable rates reflect the similarity between the age of the cut stump on which the LLL is attached and the age of the excess tree at time of treatment. Apparently the photosynthetic capacity of LLL's on 7-9 year old stumps is similar to that for 7-9 year old seedlings. In stand 2170 comparable rates are seen, through the 5 year period, between excess trees averaging ∿3 years at treatment

and LLL's on cut stumps averaging ∿8 years at treatment. That is, similar height growth was observed for 7-12 year old seedlings and 12-17 year old LLL's on 8 year old cut stumps. From the results found in stands treated in 1974-76 one would expect the older LLL's to exhibit greater height growth than that observed. Damage from the 1974 hailstorm may be responsible.

In general, the LLL's in all stands treated in 74-76 gave every indication of future height growth comparable to that of normal stems of a similar age.

Height differences. Figure 5 gives the yearly height differences between leave trees and the other residual components for the observation period. Stands are listed by year of treatment.

In all stands the height differential has increased from year to year through the period of observation. This result is expected due to the greater age of the leave trees. The greatest differentials are found in the most recently treated stands and the least in the 1967 chemically treated stands. In the stands treated in 1974-76 the tendency to leave seedlings of similar height through the 3 year period results in the larger differentials for the 1976 treatments.

In most stands the increase in the height differential also increased during the sample period. This trend can be expected to continue until the annual increase in growth rates for LLL's and Excess trees matches or exceeds the annual change for leave trees. The height growth data for 1977 and 1978 indicate that the leave tree height growth is nearing a maximum. If such is the case the differential can be expected to increase for at least the next 7-8 years (age difference between excess and leave trees) but at a decreasing rate.

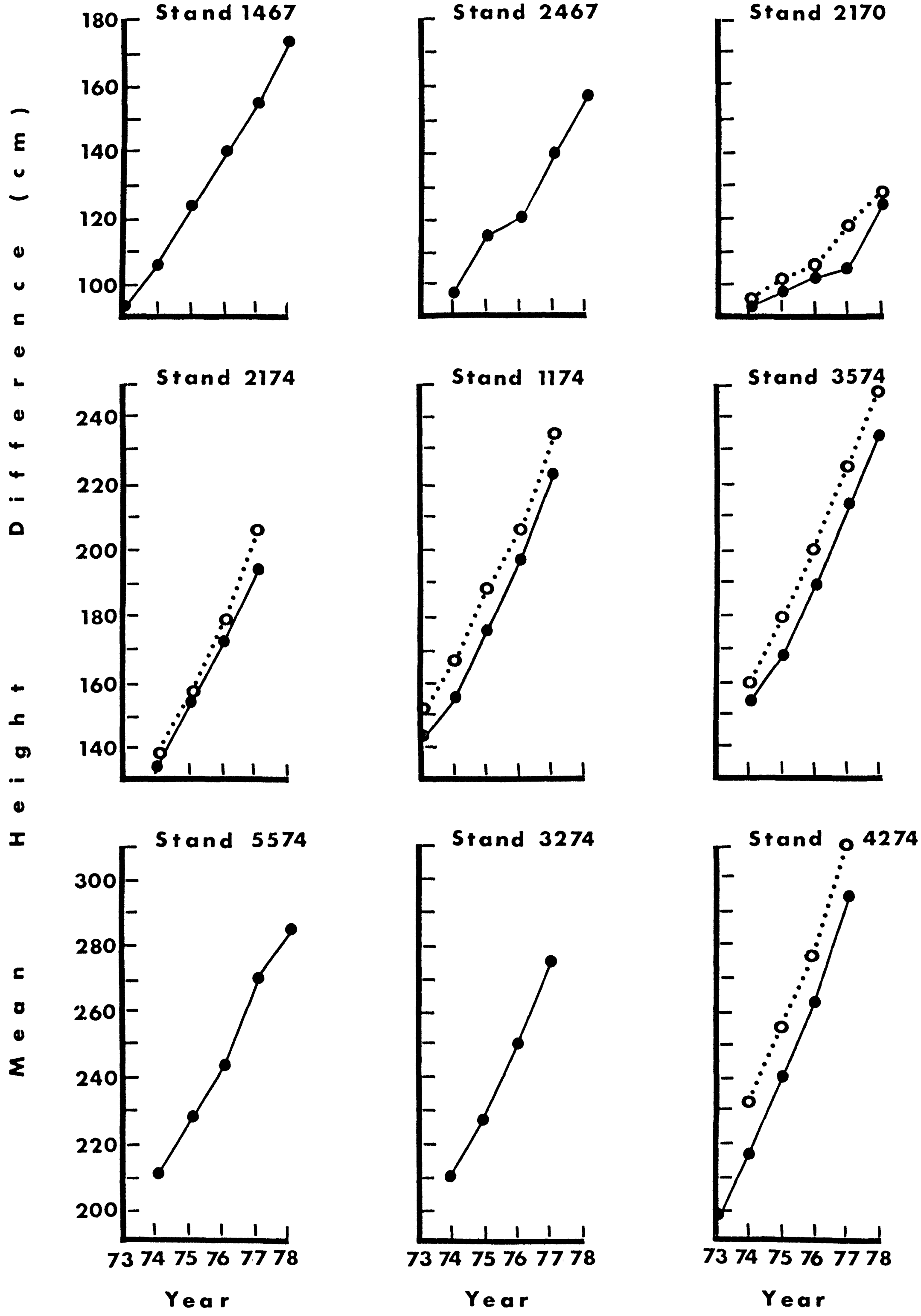

Figure 5

Mean Component Class Height Differences

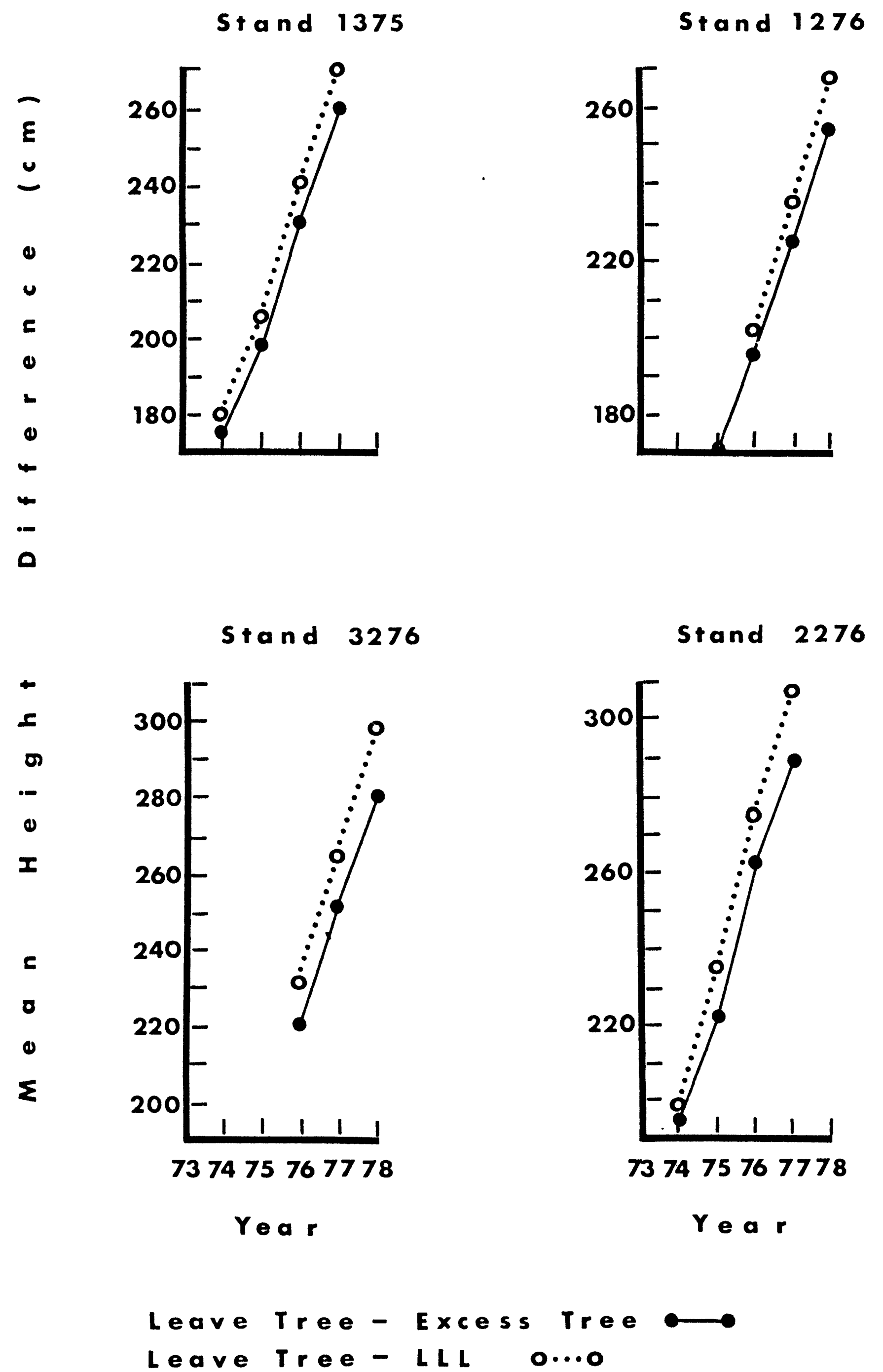

Figure 5 (cont.)

Mean Component Class Height Differences

Table 13 presents a ranking of the 13 stands according to the 1977 differential between leave trees and excess and LLL's. The mean leave tree height is also given. As might be expected, those stands of greatest leave tree height have the largest height differential. In accordance with the height data presented earlier, stands in the PSME series show a greater mean height and associated height differential than those in the ABLA series. Within the ABLA series, the MEFE h.t. generally supported stands showing greater leave tree-excess tree and leave tree-LLL differences than those for stands on the XETE h.t.

TABLE 13

Mean Height Differences - 1977
(cm)

Stand	L.T.[1]-Excess	L.T.-LLL	Mean L.T. Height	Habitat type
4274	293	308	337	PSME/CARU
2276	289	307	330	ABLA/XETE
3274	274	--	336	PSME/VAGL
5574	271	--	351	PSME/SYAL
3276	252	265	294	PSME/VAGL
1375	230	271	296	ABLA/MEFE
1276	226	236	257	ABLA/MEFE
1174	222	232	269	ABLA/MEFE
3574	214	225	268	PSME/VAGL
2174	197	207	257	ABLA/XETE
1467	153	--	263	ABLA/MEFE
2467	139	--	248	ABLA/XETE
2170	114	119	160	ABLA/XETE

[1]L.T. = Leave Tree

Response of Residual Classes

The H/CW ratio was selected as the response variable on the basis of the allometric nature of the height: crown width relationship and the differential effect of density on height and crown growth. Honer (1970) used regression analysis to investigate the height: crown width relationship in open grown balsam fir (Abies balsamea) and found it to be of the form Y = bX where Y = crown width and X = height and independent of age and site. Thus an open grown stem has a H/CW ratio approximated by the value 1/b regardless of age or the quality of the growing site. On the assumption that the same relationship is true for lodgepole pine, one would expect the H/CW ratio to have a predictable value for open grown stems, whether they be leave trees, excess trees, or LLL's. Height growth is relatively insensitive to density levels, at least within some limits, while crown growth is relatively sensitive (Smith 1962). For a given height, then, one would expect smaller crown widths in the overstocked than in the open grown condition. The H/CW ratio, therefore, would be greater in dense stands than in more open stands. On the assumption that the height:crown width relationship is independent of age, any change observed in the H/CW ratio from that at time of treatment to that in 1978 should indicate a response to increased growing space and not to some age related change in form. The same assumption should allow comparisons within stands of the mean H/CW ratios for the component classes and interpretations of differences with respect to optimum growing space. On the assumption that the height:crown width relationship is independent of site, similar comparisons and interpretations may be made for the various component classes between stands.

Characteristics of H/CW. The typical behavior of the H/CW ratio for the three component classes is shown graphically in Figure 6. The two stands were thinned in 1974 to 7' x 7' uniform spacings. They differed in initial densities and habitat type. Stand 1174 was a fairly dense, $> 10,000$ stems/acre, stand on an ABLA/MEFE h.t., while stand 2174 was only a moderately dense, $< 5,000$ stems/acre, stand on an ABLA/XETE h.t.

Especially noticeable in Figure 6 is the reduction over time in the mean H/CW ratio for excess trees and LLL's, and the apparent trend toward a similar ratio for all three component classes within 4 years of treatment. The mean ratios between stands also appear to be similar.

The decrease in the ratio since time of treatment suggests a causal link between a reduction in density and a reduced ratio. Further evidence for such a causality is found in Figure 7, which shows a plot of H/CW ratios for potential leave trees in untreated stands versus number of stems per plot. Clearly, the H/CW ratio is less on sparsely stocked plots (< 10 per plot) than on more densely stocked ones.

The convergence of the mean ratio to comparable magnitudes for each component class suggests that the ratio under conditions of reduced competition is independent of stem size, at least for the range of sizes sampled. Evidence for the validity of this independence is seen in Figure 8, where H/CW ratios for individual leave trees from the uniform 7' x 7' spacings are plotted against the associated stem diameters (DBH). The plot does not suggest any substantial relationship between tree size and the magnitude of the H/CW ratio. When the correlation coefficient, $r = \text{cov}(xy)/(\text{var } x)(\text{var } y)$, is computed for these data points, $r = 0.05$, very nearly zero.

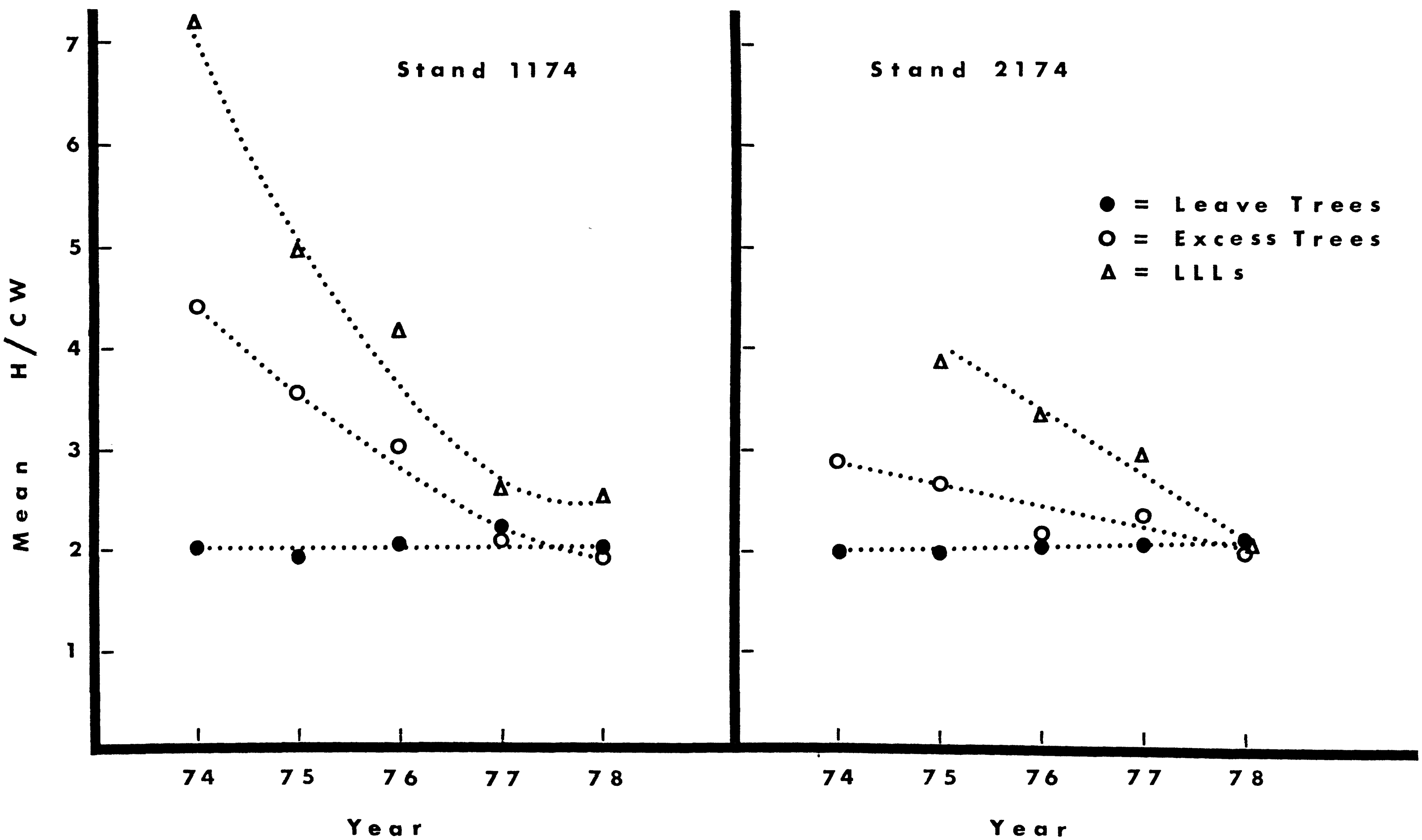

Figure 6

Mean H/CW Vs. Time by Component Class

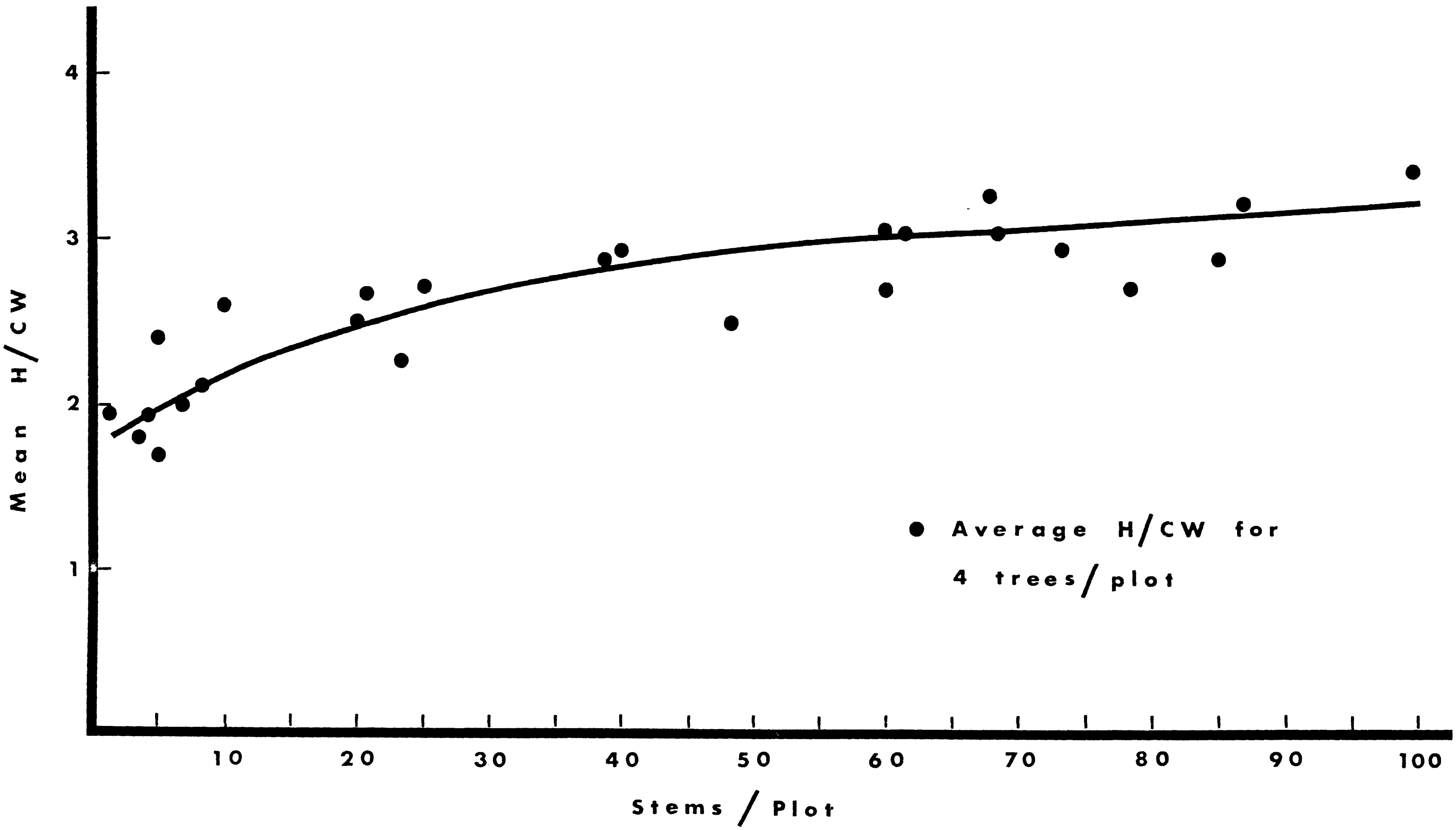

Figure 7

Mean H/CW of Potential Leave Trees Vs. Stems/Plot – Unthinned Stands

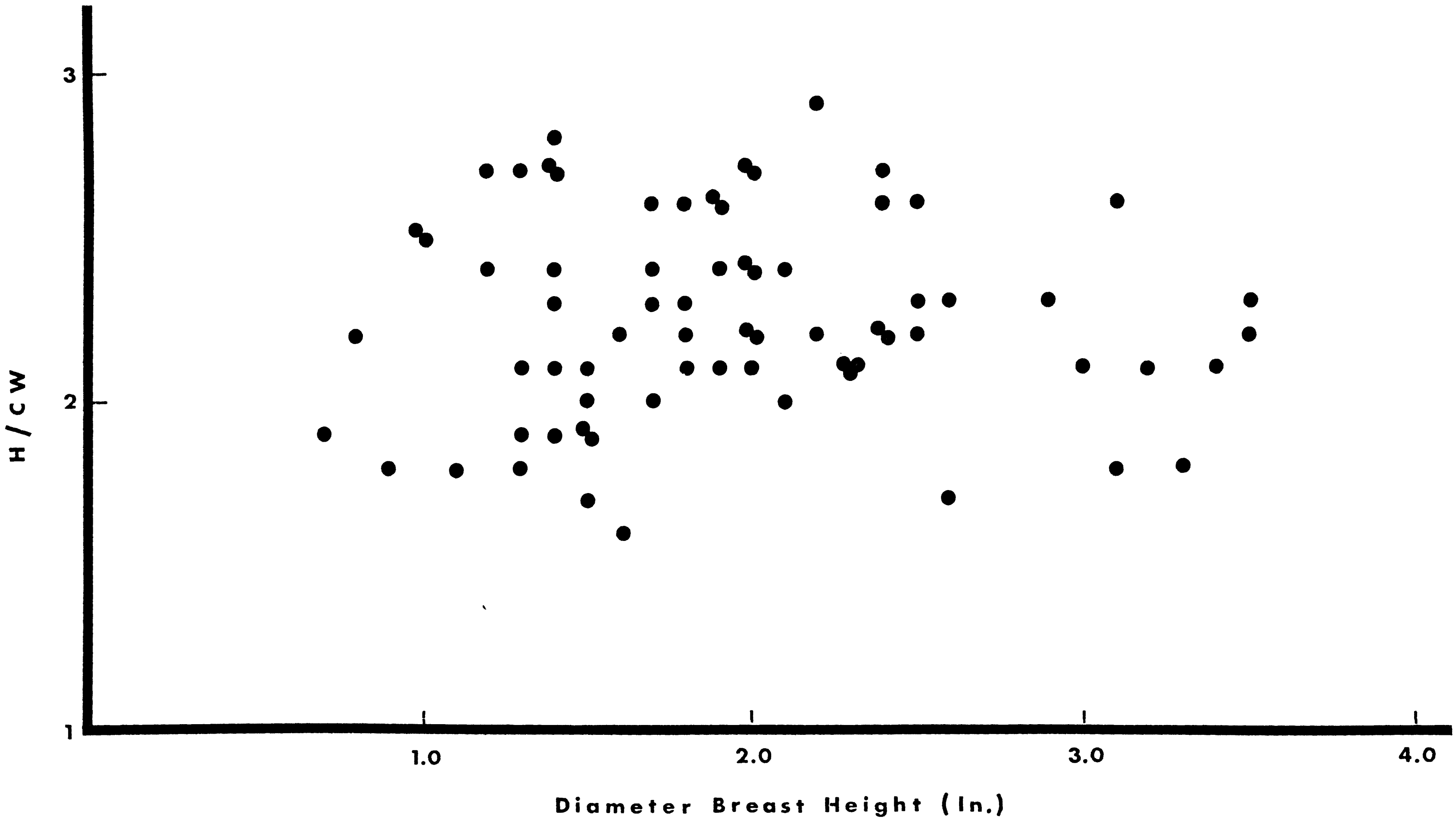

Figure 8

H/CW Vs. DBH for Leave Trees on 1974 7 x 7 ft.
Ttreatments

The similar value for the mean H/CW ratios for stands 1174 and 2174 suggests that the ratio is independent of site (as measured by habitat type). Table 14 summarizes the results of the analysis of variance used to test the null hypothesis of no difference in mean H/CW ratios for leave trees on 4 stands occurring on three different habitat types. Only those data from stands treated with uniform spacings on or before 1975 were used. The assumption was made that the difference in intra-specific competition in the 7' x 7', 10' x 10', and 12' x 12' spacings was not significant, and that any difference would be due to site. Stands 1174 ($\overline{X}_1 = 2.35$), 1375 ($\overline{X}_2 = 2.41$), 2174 ($\overline{X}_3 = 2.15$), and 4274 ($\overline{X}_4 = 2.43$) were used.

TABLE 14

ANOVA for Testing Differences

Among Mean H/CW Ratios for Leave Trees

Source	d.f.	SS	MS	F
Between Stands	3	1.04	.35	3.89
Within Stands	79	7.05	.09	
Total	82			

For $\alpha = .05$ and the given degrees of freedom the tabular F value is 2.72. Therefore the null hypothesis Ho: $\overline{X}_1 = \overline{X}_2 = \overline{X}_3 = \overline{X}_4$ is rejected and the alternative hypothesis Ha: means not all equal, is accepted. Duncan's New Multiple Range test was used to identify differences and is summarized below. For details of the test see Appendix A.

TABLE 15

Results of Duncan's New Multiple Range Test

$$X_3 \; \underline{X_1 \; X_2 \; X_4}$$

The means joined by a single underscore do not differ significantly from each other. These results show that the mean H/CW ratio for leave trees in stand 2174 was significantly less than that for stands 1375 and 4274 but no different from the mean ratio for stand 1174. The evidence is inconclusive as to whether the difference is due to change in site. Replication of sample stands within habitat types is needed for a proper analysis.

Though the above evidence is not conclusive, I feel it is sufficient to warrant the acceptance of the assumptions of independence of the H/CW ratio on age and the sensitivity of the ratio to change in competitive status. The independence of the ratio with respect to site was not demonstrated, and hence comparisons of the mean H/CW ratio between stands and interpretations of differences with respect to some optimum value cannot be made.

Analysis of Response

Table 16 gives the regression equations used to analyze the change in the mean H/CW ratio, over time, for the sample stands. Plots of the H/CW data, as in Figure 6, suggested that a simple linear model would wuffice for the purpose of identifying direction of change in the mean raio. The simple linear model $\hat{Y} = b_0 + b_1X$, where Y = H/CW and X = time, was used. Only those stands in which the H/CW ratio was calculated for 3 or more years appear in the table.

TABLE 16

H/CW Vs. Time Regression Equations

Stand	c.c	Equation	% SE	s.e.b	F
1174	1	$\hat{Y} = 1.82 + .09X$	18	.04	*4.74
	2	$\hat{Y} = 5.28 - .57X$	25	.05	*116.47
	3	$\hat{Y} = 9.09 - 1.26X$	33	.14	*80.88
1276	1	$\hat{Y} = 2.04 + 1.09X$	17	.03	.15
	2	$\hat{Y} = 2.85 - .13X$	27	.11	1.25
1467	1	$\hat{Y} = 2.00 - .02X$	25	.03	.27
	2	$\hat{Y} = 2.07 - .06X$	25	.03	2.53
2170	1	$\hat{Y} = 2.36 - .11X$	16	.02	*23.19
	2	$\hat{Y} = 3.38 - .24X$	36	.06	*16.02
	3	$\hat{Y} = 4.95 - .54X$	34	.06	*61.35
2174	1	$\hat{Y} = 1.99 + .04X$	11	.02	2.31
	2	$\hat{Y} = 3.04 - .17X$	28	.05	*9.00
	3	$\hat{Y} = 5.16 - .48X$	44	.25	3.40
2467	1	$\hat{Y} = 2.18 - .003X$	23	.03	.007
	2	$\hat{Y} = 2.72 - .18X$	31	.05	*14.38
3276	1	$\hat{Y} = 1.99 + .07X$	16	.04	2.65
	2	$\hat{Y} = 6.19 - .59X$	36	.11	*25.17
	3	$\hat{Y} = 8.49 - .93X$	30	.23	*15.32

*Model F is significantly different from zero at $\alpha = .05$.

Of interest in Table 16 are those equations which have b_1 coefficients significantly different from zero, and the signs of those coefficients. That is, in which stands did the H/CW ratio change during the 1973-1978 period and in what direction was the change?

(1) Chemical treatments. The equations for leave trees in the 1967 chemically treated stands, stands 1467 and 2467, had non-significant F's i.e. - b_1 coefficients not significantly different from zero. This result is expected since the measurement period began in 1973, 6 years after treatment, and the H/CW ratio should theoretically have previously reached the characteristic value as a result of increase growing space. The fact that the ratio has not increased indicates that intraspecific competition has not reached a level sufficient to alter the open grown dimensional relationship.

For excess trees, the b_1 coefficient is non-significant in stand 1467 but significant and negative in stand 2467. This result implies that excess trees in stand 1467 experienced no detectable change in competition during the sample period, while those in stand 2467 experienced a reduction in competition. The differences in quality of thinning and the resulting difference in competition to the excess trees is responsible for the variation in b_1 significance. Stand 1467 was a relative success, leave trees were fairly well spaced and the number of excess trees was relatively low. Excess trees in this stand experienced relatively little competition and have functioned at the characteristic ratio. Stand 2467, on the other hand, was a relative failure. While stocking was reduced by treatment, the distribution of stems is clumpy with a great many excess trees in addition to leave trees. These excess trees have grown under some greater degree of competition, therefore, than those in stand 1467. (This is evident in the greater 1973 mean H/CW ratio for excess trees in stand 2467 than in stand 1467). In the sample period these stems have evidently overcome some of the competition, hence the significant reduction in the H/CW ratio.

(2) Mechanical treatments. The results shown in Table 16 indicate that the mean H/CW ratio for leave trees either increased (Stand 1174) or failed to change significantly in the sample time period (Stands 1276, 2174, 3276). In only one case did the mean ratio show a significant decrease (Stand 2170).

The significant increase in the mean ratio found in stand 1174 appears to be the result of an unexplained increase in the 1977 mean ratio (see Table 22, Appendix B) which pulled the regression line up sufficiently to generate a significant b_1 coefficient. The mean ratios for 1976 and 1978 are noticeably less than the 1977 value. For this reason the significant increase in the mean ratio is not considered to indicate an increase in the competition experienced by the leave trees in stand 1174.

The non-significant regressions for leave trees in the remaining stands indicate that these stems have not experienced a reduction in competition, since treatment, sufficient to cause a detectable decrease in the mean H/CW ratio. The mean ratios, Table 22, Appendix B, at the beginning of the sample period are consistently lower than those for excess trees and LLL's, and show no appreciable change through the time period. It appears, therefore, that the intra-specific competition experienced by potential leave trees in the unthinned condition was insufficient to cause a reduction in crown width growth. Potential leave trees in stands treated during 1974-76 generally exhibited a degree of dominance in the various stands prior to treatment.[2] Thus they experienced no overtopping, as did excess trees and LLL's, and reduced side competition.

[2] Personal experience as crew boss and contract inspector in S.C. Burn, 1974-1977.

The mean H/CW ratios for excess trees generally decreased (Stands 1174, 2170, 2174, 3276) in the sample period, though one stand showed no significant change in the ratio (Stand 1276). In no case was a significant increase detected. The significant decrease in the ratios indicates a response of the excess trees to the increased growing space. Such a response indicates that conditions prior to treatment were sufficient to cause a reduction in crown width growth greater than that for height growth.

The non-significant regression for excess trees in stand 1276 may be explained by the difference in pre-treatment stand densities. Stand 3276, which showed a significant reduction in the mean H/CW ratio for excess trees, supported $\sim$ 10,000 stems/acre at time of treatment, while stand 1276 supported only $\sim$ 1,000 stems/acre.[3] The difference in magnitude of the 1976 mean H/CW ratio for excess trees in these two stands (see Table 22, Appendix B) corresponds to this difference in density.

The mean H/CW ratio for LLL's, with one exception, showed a significant reduction in all stands in the sample period. Such a reduction is expected as a result of the transformation from lateral to vertical stem. The H/CW ratios for LLL's as a lateral (values on or before year of treatment) are noticeably greater than for any other class of stem (Table 22, Appendix B). A significant reduction in the ratio following upturn is therefore ensured. The single exception is in stand 2174 where the value for the H/CW ratio corresponding to lateral status is missing.

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[3]Visual estimates made by author during 1976 while serving as contract inspector.

Height Characteristics at Closure

Model development. Prediction equations of the form $CW = b_0 + b_1H$ were developed for each of the six major spacings sampled. A summary of these equations is seen in Table 23, Appendix C. All regressions were significant at the 95% level. R^2 ranged from a low of .40 to a high of .93. The unexplained variability encountered, as indicated by the % standard error, ranged from 10-18%.

An analysis of covariance (Freese 1964) was employed to test for differences in b_1 coefficients. The ANOVA table given below summarizes the results.

TABLE 17

ANOVA Table for Testing Differences

Among b_1 Coefficients

Source	d.f.	SS	MS	F
Regression (Ignoring groups)	1	139747.3100	139747.3100	349.98
Residual	222	88644.2170	399.2983	
Common Levels Given Common Slopes	5	9322.7568	1864.5514	5.10
Residual	217	79321.4600	365.5367	
Common Slopes	5	6702.1064	1340.4213	3.9
Residual	212	72619.3540	342.5441	
Total	223	228391.5300		

The F value for common slopes was used to test the null hypothesis of no difference in slope:

Ho: $B_{11} = B_{12} = B_{13} = B_{14} = B_{15} = B_{16}$

HA: B's not all equal

Test statistic: $F = 3.9$

Table F $(.05, 5, 212) = 2.26$

Since $3.9 > 2.26$ reject H_0 and accept the alternative hypothesis.

A Newman-Keuls multiple range test was used to locate differences. The results of that test are given in Table 18. The individual calculations are found in Appendix D. One group of data from a stand severely damaged by hail was removed from the analysis.

TABLE 18

Results of Multiple Range Test

1 6 2 4 5

Those groups with a common underscore showed no significant difference in b coefficients. The treatments corresponding to the numbers in Table 18 are: 1 = dominant tree, 2 = chemical 12' x 12', 4 = 7' x 7' uniform, 5 = 12' x 12' uniform and 6 = 10' x 10' uniform. The results indicate no difference in the b_1 coefficients for the uniform spacings. The differences indicated between the dominant tree treatment and the other spacings are thought to be due to the use of 1978 data in the calculation of the regression coefficients for the dominant tree while 1977 data was used for all others. During a growing season the lateral shoots are noticeably upturned. The following season the new growth causes the previous lateral shoot to become more horizontal. Therefore, the H/CW ratio is greater for current dimensions than for previous years. The small b_1 coefficient for the dominant tree treatment reflects this dimensional change.

Based on these results the data for all uniform spacings was pooled, and a single regression equation produced. This equation and relevant statistics are given below:

$\hat{y} = 13.03 + .397X$, where $\hat{y}$ = predicted crown width

X = total height

$R^2 = .71$, % SE = 14%

$se_b = .05$

<u>Prediction of height at closure</u>. The crown widths necessary to cause closure as defined here, are as follows:

<u>7' x 7' uniform spacing: CW = 7' = 213 cm.</u>

<u>10' x 10' uniform spacing: CW = 10' = 305 cm.</u>

<u>12' x 12' uniform spacing: CW = 12' = 366 cm.</u>

These values are then substituted in the prediction equation and the equation solved for X, the total height at closure.[4] Table 19 gives the predicted leave tree heights at closure and 95% confidence limits for the prediction. The calculations for the 95% C.L.'s can be seen in Appendix E.

TABLE 19

Leave Tree Heights at Closure

Spacing	Predicted Height	95% CI
7' x 7'	503 cm	(415, 596)
10' x 10'	735 cm	(625, 855)
12' x 12'	889 cm	(785, 1005)

[4] The heights at closure require prediction beyond the range of the data used in estimating the regression coefficients. The predictions are considered reliable on the basis of evidence showing the H:CW relationship to be independent of age.

Calculation of date of closure. For a given stand the time to closure is determined by dividing the difference between predicted and current height by the average height growth rate of leave trees in that stand. Table 20 gives the expected year of closure based on 1977 height data.

TABLE 20

Date of Closure in Sample Stands

Stand No.	Year of Closure
1167	1992
2170	1994
1174	1985
2174	1985
3274	1991
4274	1990
1375	1995
1276	1990
3276	1989
2276	1988

These results indicate that closure will occur first in those stands thinned to a 7' x 7' spacing in 1974, followed by those stands thinned to 10' x 10' spacing in 74 and 76 and lastly in that stand thinned to a 12' x 12' spacing in 1975. Within those stands thinned to a 10' x 10' spacing, the 1976 treatments are predicted to achieve closure before the 1974 treatments. This is due to the greater height growth found in those stands treated in 1976. Evidently the extra two years in a thinned condition did not significantly increase the closure rate in those stands treated in 1974.

Height differences at closure. Table 21 gives the estimated height differences at closure for those stands where height growth and age data were available for leave trees and at least one of the other component classes. Stands are in order of increasing spacing. Excess tree and LLL heights at closure can be seen in Appendix F.

TABLE 21

Height Differences at Closure

(m)

Stand	Yr. Closure	Stand Age[1]	Stand Ht.[2]	L.T.-Excess	L.T.-LLL
1174	1985	24	5.03	2.66	2.76
2170	1994	33	5.03	1.45	--
2174	1985	24	5.03	2.44	3.05
4274	1990	29	7.35	3.49	3.45
1276	1990	29	7.35	3.41	3.46
3276	1989	28	7.35	3.58	3.66
1375	1995	34	8.89	3.17	--
1467	1992	31	8.89	2.03	--

[1] Stand age refers to age of Leave trees at closure

[2] Stand height predicted for uniform spacings, Table 19

For those stands treated with mechanical methods, the greatest differences will occur in the 1976 uniform spacings, the least differences in the 1967 and 1970 uniform spacings. This order corresponds to the 1977 height differences. The smallest predicted differences will occur in the two stands treated on or before 1970.

For all the spacings it appears that excess trees and LLL's could be ½ the height of the leave trees at closure. This is a considerable increase over the 10-20% of leave trees height seen in 1977. This projection rests largely on the assumptions that leave trees had attained maximum height growth rates by 1977 and that excess trees and LLL's would attain that rate when they reached 1977 leave tree age. The first assumption is supported by height/age curves developed by L.A. Smithers in 1961 for lodgepole pine in Alberta, British Columbia and Oregon. The slopes of these curves are relatively constant through the 10-40 year age range, indicating a constant rate of height growth in that period. The second assumption is largely unsupported. Certainly the excess tree and LLL classes are exhibiting vigorous leader growth at the present time and the open stand conditions should allow increased growth into the future. At what point crown and root competition will cause reduced growth is unknown. The projected height differences are the worst that could occur and in that sense should generate conservative recommendations for limits on excess tree and LLL heights and numbers after treatment.

Based on the projected heights it appears likely that many excess trees and LLL's will have crowns above the point of canopy closure and will therefore exert significant competition for occupancy of the site.

Characteristics of Untreated Stands

Frequency of small stems. Figure 9 shows a plot of the per acre estimates of small stems, less than 12" high, against stand density (stems/acre) for 13 untreated stands.[5] The curvilinear shape of the plot indicates relatively more small stems in high density stands than in low density stands. In stands of less than 4,000 stems/acre, small stems accounted for 0-3% of total density. In stands with over 9,000 stems/acre, small stems accounted for 5-7% of total density. The increase in relative frequency is probably due to height growth suppression of a greater number of stems in the dense stands than in the more sparse ones.

[5]Data for this plot were taken from U.S.F.S. stand exams made during the summer of 1978.

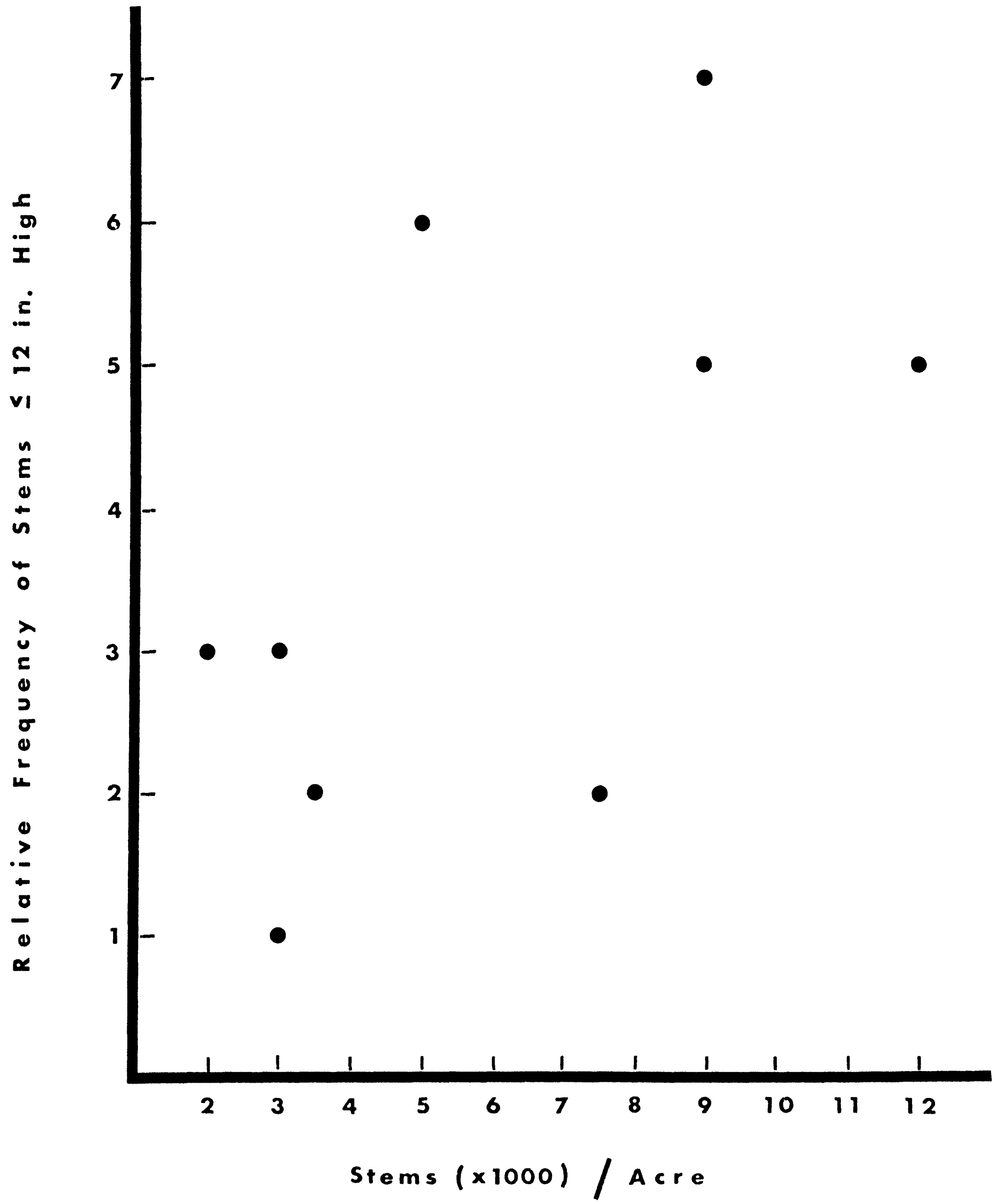

Figure 9

Relative Frequency of Stems ≤ 12 in. High

Vs. Stand Density[1]

[1] Data from USFS Stand Exams in Untreated Stands – 1978

Height to lowest live limb. Figure 10 shows a plot of mean height to the lowest live limb on 22 plots taken in 5 untreated stands. The plot shows that as density increased the mean height to the lowest live limb increased. The indicated relationship probably results from greater shading of lower live limbs in high density stands and an associated reduction in photosynthate available to these branches.

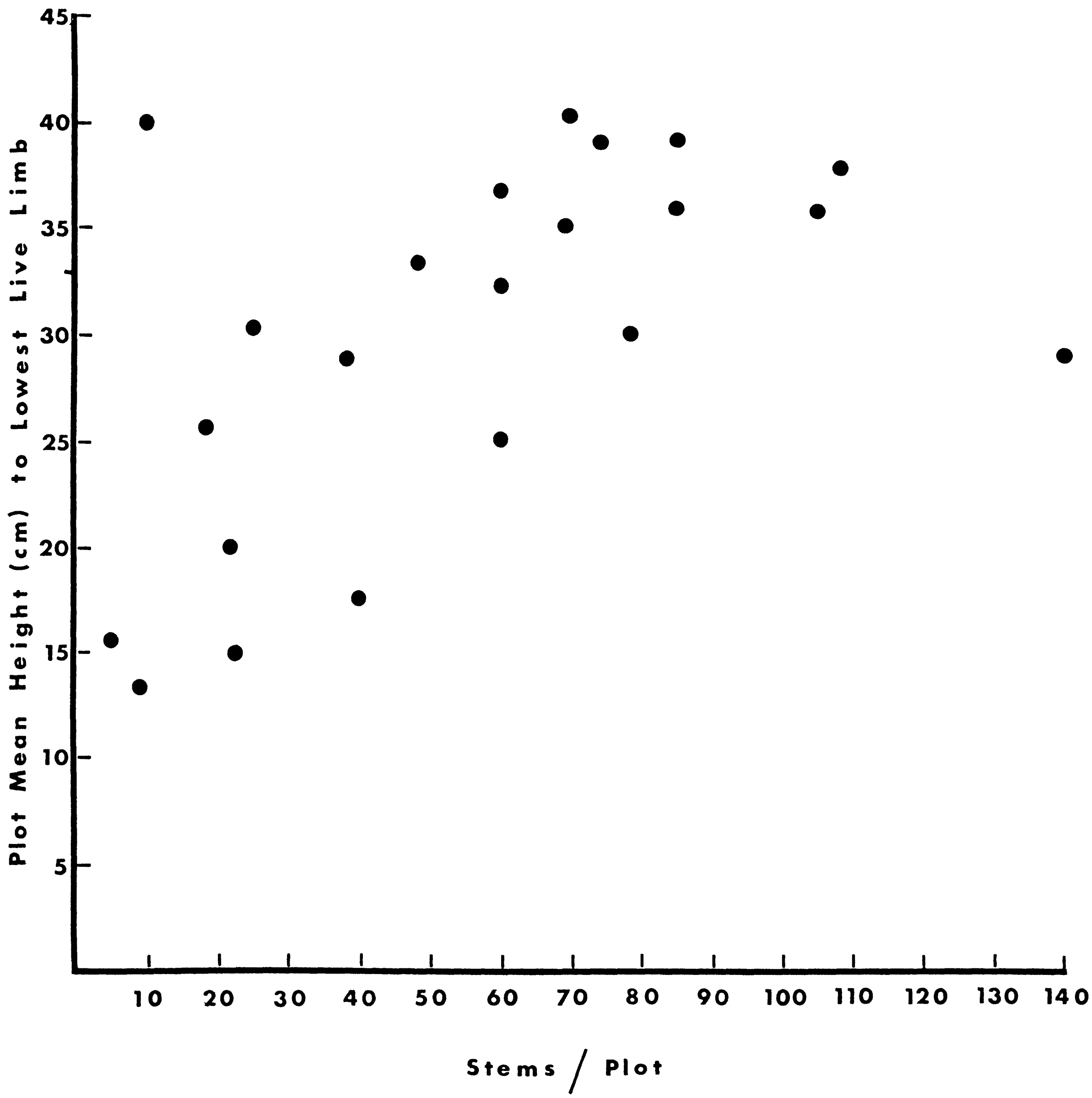

Figure 10

Mean Height to Lowest Live Limb
Vs. Plot Density[1]

[1] Data from 22 1/300 acre plots taken in 5 unthinned stands in 1978. Plot means formed for ~16 stems/plot.

Chapter 4

SUMMARY OF RESULTS

Characteristics of Component Classes

Excess tree and LLL occurrence. For all stands sampled, 90% of those stems termed excess trees in 1978 had their origins in the 7 year period from 1966-1973. The essentially bell shaped distribution of 2 year age classes for excess trees in the 1974 and 1976 treatments indicates that above 12 years old, stems are infrequently missed, and stems less than 5 years old were only occasionally present. Apparently seedling establishment virtually ceased after 1973. 90% of the LLL's existing in 1978 occurred on stumps between 5 and 10 years old regardless of time or entry. This distribution probably reflects the thinning process rather than a physiological relationship. Stems less than 5 years old are easily missed, therefore no LLL created. Stems over 10 years of age have experienced some crown recession, which reduces the probability of leaving a live lateral on the stump. The magnitude of the LLL problem will depend on the frequency of stems in this age range at time of treatment.

Both excess trees and LLL's occur as a function of their visibility (or lack thereof) through vegetation, accumulated slash, and downfall. High stand densities and/or dense understory vegetation (e.g. *Xerophyllum tenax*) which promote crown recession create a lesser problem than more sparsely stocked stands with an undeveloped shrub layer.

Comparisons with post treatment inspection reports indicate LLL survival to be between 20-50%. In one area where stumps greater than 12" high were common, 80% survival was noted. It is probable that larger laterals, with a greater photosynthetic surface, are most likely to survive.

Results of height measurements indicate that all surviving LLL's in 1978 were at least 5 cm long at time of treatment. Inspection procedures identified anything "green" as a LLL, causing buds and needle clusters to be included in LLL count. It seems likely that LLL survival percentages reflect the mortality of laterals less than 5 cm long at treatment.

The probability of leaving live laterals on the stump is partially a function of stand density. Measurements in unthinned stands in 1978 show that as density increased the height to the lowest live limb also increased. In light to moderate densities (3000 - 5000 stems/acre) the minimum height to the lowest live limb was 15 cm. In stands of high densities (more than 20,000 stems per acre) this minimum increased to 30-35 cm. These figures are significant in that traditional thinning tools (clippers, machetes, chain saws) should have no difficulty in severing stumps below the lowest live limb.

The relative frequency of small stems increased with stand density. If we assume the seed source is comparable between areas, the increased proportion of small stems (less than 12" high) in the unthinned stands probably is due to height growth suppression of stems in the larger age classes. Thus in high density stands (more than 10,000/acre) the excess tree and LLL problem will be relatively more severe than for less dense stands (less than 5,000/acre).

Excess tree and LLL growth. As indicated by the mean H/CW ratio for each class, excess trees and LLL's currently exist in an essentially open grown condition in all uniform spacings. Regression analysis shows that both classes assumed the characteristic ratio in 2-3 years after treatment and have not since experienced competition sufficient to cause detectable change.

Potential excess trees experience height growth suppression proportional to the time they exist in the unthinned condition. For approximately the same mean age, excess trees in the 1967, 1974, and 1976 uniform treatments had mean 1977 heights of 110 cm, 54 cm and 32 cm respectively. The case is similar for LLL's. Though on similar age stumps, LLL's from the 1976 treatments are smaller than those from the 1974 treatments. The additional 2 years as a lateral result in lesser 1978 heights for the 1976 LLL's.

There is no clear correspondence between height growth of excess trees and LLL and site, as expressed by habitat type. As indicated above, different dates of entry have masked the effect of site on height growth. Within the 1974 treatments slightly higher rates are found in the ABLA series than in the PSME series.

Height growth of excess trees in the 1967 treatments is roughly double that for excess trees in the 1974-76 treatments. Such a difference is undoubtedly due to the fact that the excess trees in the 1967 treatments originated after treatment and hence have not experienced the competition felt by similar stems in the 1974-76 treatments.

Leave tree growth. Annual leave tree height growth generally increased 5-10 cm through the 5 year observation period. Since most studies have shown little or no height growth response to thinning (Quaite 1950, Smithers 1957) it is felt that this increase is age dependent in nature. Height/age curves developed by L.A. Smithers (1962) show that the maximum height growth rate is attained between ages 15-20 years for lodgepole pine in British Columbia and Alberta. The sample stands were all 17 years old in 1978 and hence the 1978 height growth figures represent the maximum rates to be expected. On an individual stand basis such factors as hail, fungi, and insect damage have prevented the maximum from being attained.

Site differences, as indicated by habitat type, were not reflected in differing height growth rates. When grouped by habitat type, the 1977 height growth estimates were all within a few centimeters of each other. However, the total height estimates showed the least mean leave tree height in the ABLA series types and the greatest on the PSME series types.

The regression analysis showed that the mean H/CW ratio for leave trees did not change significantly in the study period (1973-78). This event is in sharp contrast with that seen for excess trees and LLL's, which generally showed a significant drop in the ratio. The theoretical interpretation of this "no change" event is that the leave trees, as a class, have not experienced a reduction in intraspecific competition since treatment. The immediate conclusion is that prior to treatment these stems were not experiencing competition sufficient to alter the H/CW relationship characteristic of open grown stems. A conspicuous hypothesis, based on this conclusion, is that these stems were also not suffering any loss of growth in the overstocked condition. Had such a loss been occurring prior to treatment it would have resulted in reduced crown growth and would have been manifested in a higher H/CW ratio. Since there was no significant change in the ratio since treatment (1974-76 treatments) it is concluded that any growth loss experienced by leave trees was insufficient to be reflected in the H/CW ratio. Additional data, especially diameter growth, are needed to calibrate the relationship between H/CW and growth. In the absence of such data it seems reasonable to conclude that for the stand age and densities found in the Sleeping Child Burn, entry for purposes of securing and controlling growth can be delayed at least until stand age is 15 years.

Competition from excess trees and LLL's. The predicted component class heights indicate that excess trees and LLL's will be at least ½ the height of leave trees at closure. For stands treated in 1967 and 1970, the height differences will be even less. Generally the predicted differences are least for early thinnings to a wide spacing and greatest for later thinnings to a more moderate spacing.

On the basis of predicted height at closure it appears that excess trees and LLL's might be able to successfully compete with the leave trees for available growing space, thereby reducing the success of the stocking control treatment. The magnitude of the competition will depend on the functional crown area of these stems. A tall whiplike stem with only a tuft of crown near the top will not take much away from a full crowned leave tree. The photosynthetic surface of excess trees and LLL's at closure will depend on two factors: the water deficits experienced by excess tree and LLL root systems and the height of the leave tree canopy at closure. Reduced photosynthetic rate due to water stress slows growth, particularly diameter growth (Kozlowski 1958). A concommittant reduction in crown growth would occur also. Thus root competition from vigorous leave trees could significantly reduce the quantity and quality of the excess tree and LLL crowns. The height to the canopy will determine how much of the excess tree and LLL crown extends into the general canopy level. Honer (1970) developed a prediction equation for open grown Balsam fir which predicted the height to the point of widest crown to be approximately .2 of total tree height. Observation of open grown stems suggest that this value is reasonable for lodgepole pine as well. The predicted excess tree and LLL heights at closure are well above this value (more than .5 in all stands). This predicted height assumes normal growth rates for excess trees and LLL's in the time prior to closure. The height and age data for excess trees and LLL's indicates that some loss of height growth occurs for stems which are completely overtopped. Thus the spatial distribution of excess trees and LLL's with respect to leave trees may greatly influence the height of a given stem at crown closure. Those LLL's and excess trees which are midway between two leave trees may show normal growth, while those stems closer to leave trees may experience reduced height growth. At the time of this study the mean H/CW ratios for LLL's and excess trees indicated that these stems were not experiencing significant competition in any of the sample stands. Evidently root and crown competition from the leave trees has not significantly affected the growth of these stems. When and to what extent growth will be affected is unknown. However, the safest prediction is that LLL's and excess trees created in stands less than 16 years of age will likely attain intermediate and perhaps codominant status in the canopy.

Seedling establishment. The age data indicate that seedling establishment in the Sleeping Child Burn continued well beyond the 1-2 years reported by Lyon (1976). In the most recent treatments sampled, 1976, 25-30% of the excess trees originated in 1970-71. In the 1967 chemical treatments virtually all of the excess trees found in 1978 originated after time of treatment.

There appear to be two general cases of seedling establishment that must be considered when planning an early stocking control entry: the duration of establishment in unthinned stands, and the probability of establishment after the stand is opened up. The first is important with respect to the number of small stems encountered (source of excess trees and LLL), the second with respect to the height differences created between leave trees and any seedlings established after treatment.

In most of the sample stands treated after 1974, the youngest excess trees were 5 years old in 1978. Thus, seedling establishment in unthinned stands was virtually complete in 1973, 12 years after the burn. Complete crown closure and a developed understory probably created unsatisfactory germination and seedbed requirements. A cessation of seed source may also have contributed. From these results it is concluded that to minimize the number of small stems encountered during treatment, entry should be delayed a number of years past the end of seedling establishment. The period of time should be sufficient to allow mortality of the newest seedlings from competition or to insure the stems are of a size sufficient to be easily seen. In the case of the Sleeping

Child Burn a 5 year period seems reasonable. Thus, entry should not occur in the first 17 years following the burn.

If a stand is opened up before seedling establishment is complete, as in the case of the 1967 chemical treatments, the existing seed source will immediately begin filling in the stand. Since the stand is very young, 6 years in the above case, the height differences between leave trees and the new seedlings are relatively small. Without further entry, the probability is high that the stocking desired will not be obtained. The seed source in this case is probably serotinous cones. The increased temperatures and moisture variation caused by removal of the overstory would cause flexing of cone scales and the accompanying release of seed (Crossley 1956). These cones might be ones which only incompletely opened prior to development of a canopy or those from the many snags remaining in the area at that time.

In stands treated after 1974, seedling establishment has been minimal. In one stand 45 seedlings per acre were counted, far less than the numbers encountered in the 1967 sample stands. The seed source for these seedlings is probably the last of the serotinous cones on the remaining snags, and non-serotinous cones on sexually mature leave trees. The moderate contribution from these sources may be due to poor seedbed characteristics caused by a well developed grass and shrub understory. In addition to the relatively small number of new seedlings, the height differences between leave trees and these new stems is quite large. Competition from these stems should be minimal.

Chapter 5

RECOMMENDATIONS

Treatment Type

Chemical treatments have had the least success. Though lower in initial cost than mechanical methods, incomplete kill of undesirable stems and continued seedling establishment after treatment have effectively nullified the stocking control effort. Chemical methods, as applied in the Sleeping Child Burn, require entry while stand heights are small, in order to bag crop trees, and hence competition to leave trees from new seedlings and surviving undesirable stems is assured. The possibility of contamination by components of Dacamine 4-D in the soil and water further contributes to the unsuitability of chemical treatments.

Mechanical methods offer the best chance of success in securing a desired level of stocking. Though costs are higher than for chemical treatments, as applied in the Sleeping Child Burn, spacing and timing of entry can vary in order to minimize competition from excess trees and LLL's.

Timing of Entry

Stocking control efforts by mechanical methods should be delayed until seedling establishment is complete and crown recession on the small stems is sufficient to ensure a low probability of live limbs left on cut stumps. The results of the H/CW analysis suggest that significant growth loss by eventual leave trees had not occurred prior to entry in any of the stands treated on or before 1976. Thus, a delay in entry sufficient to minimize the excess tree and LLL problem is justified. In the Sleeping Child Burn, post fire seedling establishment continued for approximately 12 years in the sample stands. By 1978, 17 years following the fire, the mean height to the lowest live limb in unthinned stands was at least 15 cm, a height sufficient to ensure that cutting methods will be successful in eliminating LLL's. In very dense stands crown recession is more rapid and date of entry could be earlier than the 17 year figure.

Mechanical methods in stands less than 10 years old are not advised. The probability of new seedling establishment is high, the number of potential LLL's and excess trees is high, and the height differences created between leave trees and the other component classes are small. A second pre-commercial entry would probably be necessary to maintain the desired stocking level.

In older stands the LLL and excess tree problem is somewhat less serious, though small stems and potential LLL's are still abundant. Chances for success of a single pre-commercial entry vary according to stand density, leave tree height and the frequency of small stems. Generally, high density stands on good sites will pose the fewest problems with respect to excess tree and LLL occurrence. Crown recession will have been more rapid and the youngest stems will be taller, thereby reducing the chance for LLL or excess tree occurrence. High density stands on poor sites may present the greatest problem. Potential leave trees are small and live limbs at ground level are common. The potential for excess trees and LLL's is high and the height differences created are small. The worst of such stands were encountered on sites where high densities and high water stress combined to severely retard tree growth. There does not seem to be any economic or biological justification for investing in such stands for timber objectives.

Spacing

As a rule of thumb, where excess trees and LLL's pose a problem, the younger the stand the tighter the spacing should be. Wide spacings should be avoided so that the excess trees and LLL's created spend less time in a relatively competition free environment prior to closure of leave tree crowns. Fewer cut stems mean less slash, hence less opportunity to miss small stems. Crown closure of leave trees will occur sooner, offering greater shading of excess trees and LLL's. Casual observations in several stands treated in 1974 by the dominant tree method revealed those areas to be relatively free from LLL's. Crown closure had occurred in those stands and it is conceivable that the increased shade caused significant mortality of the LLL's.

Numbers of LLL's and Excess Trees

The predictions of component class height differences at closure indicate that in all stands treated through 1976, excess trees and LLL's will be in the general canopy. In the earliest treated stands, 1967 and 1970, the predicted height differences are so small that excess trees and LLL's should be considered nearly equal competitors for site occupancy with the leave trees. If such young stands have to be entered, total stocking level should be the sum of stems in all 3 component classes. Thus, stringent contact specifications concerning numbers of excess trees and LLL's left following treatment would be necessary. In the stands treated in 1976, projected height differences are twice those for stands treated prior to 1970. Though still in the canopy, LLL's and excess trees in these stands should not be considered equal competitors with leave trees. Thus a greater number of LLL's and excess trees could be tolerated following treatment.

Implementation of Mechanical Treatments

Tools. In stands with an abundance of small stems hand tools are necessary. Power tools (chain saws, brush cutters, etc.) are inefficient at cutting small stems and there is a high user reluctance to go after limbs at or near ground level. Downfall, brush and rocky terrain further limit the usefulness of these tools. Long handled snippers and machetes have been used successfully. The snipper is without equal in severing stumps below the lowest live limb, easily cuts small stems, and when sharp can handle a 3" stem. The snipper is especially valuable in areas where small trees are growing underneath and around downfall. The tool is easily sharpened and broken handles, which occur infrequently when properly used, are easily replaced. Machetes have also proven successful though their maneuverability is less than for snippers and the potential for hand, leg, and foot injuries is higher. This tool is superior to the snipper on larger stems, is lighter, less likely to break, and, like the snipper, is easily sharpened and requires few accessories.

Crew organization. An efficient, high quality operation depends on proper supervision. In my experience, 5-6 persons per working supervisor yielded the best results. While it is tempting to have 10-15 persons working in a single area under a single crew boss in order to maximize immediate production, such a large crew usually results in a loss of quality control and individual production. It is better to have several crews working in separate areas.

In the Sleeping Child Burn, most stands were on slopes between 10-40%. For uniform spacings the most efficient approach is to thin uphill, with workers spaced about 10 feet apart. Cut trees fall downhill, into thinned areas, and not into unthinned areas or onto fellow workers. The 10 foot wide swath per individual is sufficient to prevent excessive socializing but not so much as to be psychologically overwhelming. It is important to designate one person as a guide, who can maintain a straight line uphill. The other crew members can key on him and be assured that an approximately equal area is being treated by each individual.

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Appendix A

Duncan's New Multiple Range Test

From the analysis of variance we have the within stand variation estimated by $S^2_w = .09$ with degrees of freedom, d.f. = 79.

STEP 1. For each sample, a value, $q'_\alpha(r,v)$, where r = sample number, v = degrees of freedom and α = level of significance is read from a table of q' values.

STEP 2. For each sample, r, a value $w_r = q'_\alpha(r,v)\sqrt{\frac{S^2_w}{\tilde{n}}}$ where r, v, q', α, and S^2_w are as before and $\tilde{n}$ is a combined sample size calculated by $\tilde{n} = \frac{\text{no. samples}}{\frac{1}{n_1} + \frac{1}{n_2} + \ldots + \frac{1}{n_r}}$, is calculated.

STEP 3. Sample means are then arranged in order of increasing magnitude. Beginning with the largest value the sample means are compared to the smallest mean and each difference compared to the w_r value for the larger of the two values. Where $\bar{Y}_i - \bar{Y}_j$ is greater than w_r a significant difference is noted.

For the four samples, r = 2, 3, 4, 5, we get:

r	2	3	4	5
$q'_\alpha(r,v)$	2.82	2.96	3.07	3.13
w_r	.23	.24	.25	.25

Ordering the samples by increasing means, we get:

Sample	3	1	2	4
Sample mean ($\bar{Y}$)	2.15	2.35	2.41	2.43

Beginning with samples 3 and 4 the comparisons with w_r are:

Comparison	Conclusion
$\overline{Y}_4 - \overline{Y}_3 = .28$	$> .25$; Proceed
$\overline{Y}_2 - \overline{Y}_3 = .26$	$> .25$; Proceed
$\overline{Y}_1 - \overline{Y}_3 = .20$	$< .23$; Stop
-- -- -- -- --	-- -- -- -- --
$\overline{Y}_4 - \overline{Y}_1 = .08$	$< .24$; Stop
-- -- -- -- --	-- -- -- -- --
$\overline{Y}_4 - \overline{Y}_2 = .02$	$< .23$; Stop

A summary of indicated significant differences is:

3 1 2 4

All samples not underlined by a common line have means that are significantly different from each other.

Appendix B

Table 22. Mean H/CW Ratios by Component Class and Year ($\bar{X}$, s)

STAND No.	c.c.[1]	1973	1974	1975	1976	1977	1978
1174	1		(2.08, .59)	(1.97, .42)	(2.00, .34)	(2.35, .35)	(2.17, .27)
	2		(4.24, .96)	(3.56, .83)	(2.96, .92)	(2.28, .44)	(2.12, .27)
	3		(7.35, 2.17)	(4.94, 1.16)	(4.18, 1.51)	(2.59, .74)	(2.56, .61)
1276	1		(2.12, .54)	(2.04, .39)	(2.04, .31)	(2.09, .23)	(2.15, .22)
	2			(2.53, .92)	(2.23, .59)	(2.32, .56)	(2.07, .50)
1467	1	(2.24, .92)	(1.94, .71)	(1.81, .35)	(1.82, .30)	(1.88, .31)	(2.02, .29)
	2	(2.34, 1.00)	(2.00, .59)	(1.73, .40)	(1.73, .38)	(1.75, .30)	(1.85, .33)
1375	1					(2.41, .21)	
	2					(2.82, .87)	
2170	1		(2.22, .50)	(2.01, .33)	(1.86, .21)	(1.78, .19)	(1.81, .20)
	2		(2.76, .83)	(2.75, 1.04)	(2.49, 1.01)	(2.05, .74)	(1.96, .52)
	3			(3.41, 1.27)	(2.69, .82)	(1.97, .58)	(1.88, .44)
2174	1		(2.19, .26)	(2.06, .19)	(2.07, .17)	(2.15, .26)	(2.38, .16)
	2		(2.81, .70)	(2.57, .75)	(2.09, .41)	(2.31, .78)	(2.00, .23)
	3			(3.68, 1.16)	(3.12, 1.27)	(2.88, 1.48)	(2.09, .93)

STAND NO.	c.c.	1973	1974	1975	1976	1977	1978
2276	1		(2.31, .04)	(2.28, 101	(2.35, .08)	(2.44, .18)	(2.46, .16)
	2		(2.26, .52)	(2.13, .18)	(2.05, .34)	(2.08, .48)	(1.92, .55)
2467	1	(2.45, 1.02)	(2.01, .34)	(2.02, .31)	(2.06, .27)	(2.16, .23)	(2.34, .27)
	2	(2.90, 1.11)	(2.25, .59)	(2.05, 177)	(1.76, .38)	(1.77, .32)	(1.94, .41)
3276	1				(2.28, .40)	(2.36, .38)	(2.43, .36)
	2				(3.82, 1.51)	(3.28, 1.17)	(2.64, .72)
	3				(5.09, 2.64)	(3.74, 1.11)	
3574	1						(2.30, .39)
3274	1						(2.46, .33)
4274	1					(2.43, .28)	
	2					(2.53, .55)	
	3					(2.27, .26)	
5574	1						(2.96, .49)

[1]c.c. = component class

Appendix C

TABLE 23. Crown Width Vs. Height Regression Equations

Spacing	Equation[1]	Statistics[2]	
1. Dominant Tree	CW = 52.44 + .24H	F = 24.17	n = 40
		%SE = .18	
		R^2 = .40	
2. Chemical	CW = -17.60 + .58H	F = 21.57	n = 23
		%SE = .16	s.e.b. = .12
		R^2 = .51	
3. Uniform 7' x 7'	CW = 13.72 + .39H	F = 205.3	n = 75
		%SE = .14	s.e.b. = .02
		R^2 = .74	
4. Uniform 10' x 10'	CW = 25.23 + .36H	F = 63.32	n = 55
		%SE = .15	s.e.b. = .04
		R^2 = .54	
5. Uniform 12' x 12'	CW = -19.79 + .49H	F = 126.35	n = 11
		%SE = .10	s.e.b. = .04
		R^2 = .93	

---

[1] In all equations, CW = crown width and H = height. 1977 dimensions were used throughout.

[2] F refers to model F = $\frac{\text{Regression SS}}{\text{Residual SS}}$, %SE = $\frac{\text{SE}}{\text{mean CW}}$, $R^2 = \frac{\text{Regression SS}}{\text{Total SS}}$, n = sample size, and s.e.b. = (MSE)(v_{ii}) where MSE = estimate of σ^2 and v_{ii} are diagonal elements of $(x'x)^{-1}$ matrix.

Appendix D

Newman-Keuls Multiple Range Test

STEP 1. An estimate of the variance using pooled data is obtained by $(S^2 y \cdot x)p = \Sigma\text{Residual SS}/\Sigma\ \text{Residual DF}$.

STEP 2. An estimate of the standard error associated with the difference between any pair of b_1 coefficients is obtained from

$$SE = \sqrt{\frac{(S^2 y \cdot x)p}{2}\left[\frac{1}{(\Sigma x^2)_A} + \frac{1}{(\Sigma x^2)_B}\right]}$$

, where $(S^2 y \cdot x)p$ is as in step 1, and $(\Sigma x^2)_A$ and $(\Sigma x^2)_B$ are corrected sums of squares from regressions A and B respectively.

STEP 3. The statistic $q = \frac{b_A - b_B}{SE}$, where b_A and b_B are coefficients from regressions A and B, is calculated for each pair of equations.

STEP 4. The test statistic q is compared to the q value read from the appropriate table to test the null hypothesis

$$H_0\colon b_i = b_j$$

$$H_A\colon b_i \neq b_j$$

If test q > table q then H_0 is rejected.

From the individual regressions we obtain:

$$(S^2 y \cdot x)p = \frac{\Sigma RSS}{\Sigma Rdf} = 366.46$$

The critical value $q(\alpha, Pdf, c)$ is found to be 3.858, for $\alpha = .05$, $Pdf = \infty$, and $c = 5$ (number of groups). The comparisons of all pairs of coefficients and the respective results are summarized below.

Regressions	SE	q	Table q	Decision
1 & 2	.08613	3.92	3.858	Reject H_0
1 & 3	.03563	4.43	3.858	Reject H_0
1 & 4	.04363	2.71	3.858	Accept H_0
1 & 5	.05319	4.69	3.858	Reject H_0
2 & 3	.08393	2.18	3.858	Accept H_0
2 & 4	.08763	2.51	3.858	Accept H_0
2 & 5	.09276	1.67	3.858	Accept H_0
3 & 4	.03913	1.01	3.858	Accept H_0
3 & 5	.04956	1.84	3.858	Accept H_0
4 & 5	.05560	2.35	3.858	Accept H_0

The results of these comparisons may be written

$$\underline{1 \quad 4} \quad 2 \quad 3 \quad 5$$

Where a common underline indicates no significant difference in b_1 coefficients.

Appendix E

95% Prediction Limits for $\hat{X}$

The prediction equation Y = 13.03 + .397X, where Y = crown width and X = height, was developed from the pooled data of all uniform spacings. The prediction limits for $\hat{X}$ are calculated as follows:

$$(1) \qquad UPL = \bar{X} + \frac{1}{1-c^2}\left[(\hat{X} - \bar{X}) + \frac{t_{\alpha/2}S}{\hat{B}_1}\sqrt{\frac{n+1}{n}(1-c^2) + \frac{(\hat{X} - \bar{X})^2}{SS_{xx}}}\right]$$

$$(2) \qquad LPL = \bar{X} + \frac{1}{1+c^2}\left[(\hat{X} - \bar{X}) - \frac{t_{\alpha/2}S}{\hat{B}_1}\sqrt{\frac{n+1}{n}(1-c^2) + \frac{(\hat{X} - \bar{X})^2}{SS_{xx}}}\right]$$

Where: $S^2 = \frac{SSE}{n-2}$ $\qquad c^2 = \frac{t_{\alpha/2}S^2}{\hat{B}_1 \; SS_{xx}}$

and $t_{\alpha/2}$ is based on n-2 degrees of freedom.

From the calculation of the pooled regression equation we get SS_{xx} = 674,391.6 and S^2 = 314.522. From these values c^2 = .01 and $1-c^2$ = .99. Sample size, n, is 141 and $\hat{B}_1$ = .397.

For the three major spacings the prediction limits for $\hat{X}$ based on crown width (Y), mean height ($\bar{X}$) and predicted height ($\hat{X}$) are given below:[1]

Spacing	Y	$\bar{X}$	$\hat{X}$	UPL	LPL
7' x 7'	213	280	503	597	415
10' x 10'	305	280	735	855	625
12' x 12'	366	280	889	1005	785

[1]Units on all values are centimeters.

Appendix F

Calculation of Excess Tree and LLL Height at Closure

The total height at closure is estimated by:

(1977 height) + (annual height growth through time period = age difference) + (height growth until closure)[1]

This may be expressed algebraically as:

$$(1)\ HC = e + b+c + b+2(c) + b+3(c) + \ldots + b+a(c) + d(b+a(c))$$

Where a = age difference

b = 1977 height growth for LLL or excess trees

c = average annual increment of height growth of LLL or excess tree

d = years to closure - age difference

e = 1977 height of excess trees or LLL's

HC = height at closure

Collecting like terms in (1) we get

$$(2)\ HC = a(b) + c(a(\frac{1+a}{2})) + d(b + a(c)) + e$$

The calculations of height at closure for excess trees and LLL's, using (2), for each stand are summarized in the following table.

---

[1] In all stands the age difference between leave trees and excess trees and/or LLL's was less than the total time to closure. The last term is therefore always positive.

TABLE 24

Input Values[3] for the Calculation of

Excess Tree and LLL Height at Closure

Stand	cc[2]	a	b	c	d	e	HC
1174	2	7	8	3.6 cm	1	47	237 cm
	3	7	8	3.6	1	37	227
2170	2	6	9	1.8	11	46	358
2174	2	7	13	2.7	1	60	259
	3	6	9	3.8	2	50	265
4274	2	8	8	3.13	5	44	385
	3	6	6	4.5	7	29	391
1276	2	8	6	3.8	5	31	394
	3	7	3	4.7	6	21	389
3276	2	8	7	3.7	4	42	377
	3	7	4	4.6	5	29	369
1375	2	7	4	4.4	11	35	572
1467	2	8	25	2.2	7	110	685

[2]cc = component class. Excess trees = 2, LLL's = 3.

[3]a = age difference, b = 1977 height growth, c = average annual increment of height growth, d = years to closure - age difference, e = 1977 height, HC = height at closure.

Appendix G

List of Abbreviations

ANOVA	analysis of variance
cc	component class
cm	centimeter
cov	covariance
c.v.	coefficient of variation
d.f.	degrees of freedom
h.t.	habitat type[1]
H/CW	Height/Crown Width
LLL	lower live limb
MAI	mean annual increment
MS	mean square
r	sample correlation coefficient
s	standard deviation
SS	sum of squares
U.S.F.S.	United Stated Forest Service
var	variance
$\overline{X}$	mean of independent variable
$\overline{Y}$	mean of dependent variable

[1]A habitat type is designated by a potential overstory climax species and a potential understory union. Those types referred to in this study are: Abies lasiocarpa/Menziesia fernugina = ABLA/MEFE, Abies lasiocarpa/ xerophyllum tenax = ABLE/XETE, Pseudotsuga menziesii/Vaccinium globulare = PSME/VAGL, Pseudotsuga menziesii/Calamagrostis rubescens = PSME/CARU, and Pseudotsuga menziesii/Symphoricarpos albus = PSME/SYAL.

Appendix H

Stand List for Sleeping Child Burn Thinning

1967 - 1979

CHEMICAL TREATMENTS[1]

Area No.	Bagged Trees/Acre	Year	Acres
1	300	1968	200
2	200	1969	300
3,4,5,6	200	1969	800
7,8,9	200	1969	876
10	300	1967-68	651

MECHANICAL TREATMENTS - DARBY R.D.

Stand No.	Type	Year	Acres
57·1·04	Crop Tree	1975	128
57·1·05	Crop Tree	1975	13
57·2·09	Crop Tree	1975	75
57·3·14	Crop Tree	1975	123
58·1·15	Crop Tree	1975	51
58·1·16	Crop Tree	1975	129
58·1·22	Crop Tree	1975	40
59·2·08	Crop Tree	1976	50
59·2·09	Crop Tree	1976	59
59·2·10	Crop Tree	1976	46
59·2·11	Crop Tree	1977	42
59·3·13	Crop Tree	1976	20
59·4·40	Crop Tree	1971	132
59.4.06	Crop Tree	1971	25
59·4·08	Crop Tree	1977	82
59·4·09	Crop Tree	1979	42

[1] All Chemical Treatments used Dacamine 4-D. All areas treated from helicopter except area 10 which was done with backpack mistblower.

MECHANICAL TREATMENTS - SULA R.D.

Stand No.	Type	Year	Acres	Labor
301·1·26	10x10'	1977	49	Contract
301·1·28	10x10'	1977	16	Contract
301·2·25	10x10'	1977	31	Contract
301·2·26	10x10'	1977	12	Contract
301·2·27	10x10'	1977	26	Contract
301·2·28	10x10'	1977	18	Contract
301·2·29	10x10'	1977	76	Contract
301·2·31	10x10'	1976	41	Contract
301·2·32	10x10'	1976	13	Force Account
301·2·33	10x10'	1976	41	Force Account
301·2·34	10x10'	1976	50	Contract
301·2·35	10x10'	1977	21	Force Account
301·2·36	10x10'	1977	29	Force Account
301·2·37	10x10'	1977	20	Contract
301·2·38	10x10'	2977	29	Contract
301·2·39	10x10'	1977	10	Contract
301·2·40	10x10'	1977	15	Contract
301·2·41	10x10'	1976	36	Contract
301·2·42	10x10'	1977	22	Contract
301·2·43	10x10'	1977	73	Force Account
301·2·44	10x10'	1979	53	Contract
301·2·45	10x10'	1978		YCC
301·2·46	10x10'	1978	69	Force Account
301·2·04	10x10'	1979	57	Force Account
301·3·14	10x10'	1977	89	Force Account
301·3·15	10x10'	1976	42	Contract
301·3·16	10x10'	1976	60	Contract
301·3·17	10x10'	1977	17	Contract
301·3·18	10x10'	1977	12	Contract
301·3·19	10x10'	1976	27	Contract
301·3·20	10x10'	1976	14	Force Account
301·3·21	10x10'	1976	27	Force Account
301·3·22	10x10'	1976	18	Force Account

Stand No.	Type	Year	Acres	Labor
301·3·23	10x10'	1976	64	Force Account
301·3·24	10x10'	1977	17	Contract
301·3·25	10x10'	1976	15	Force Account
301·3·26	10x10'	1979	43	Contract
301·3·27	10x10'	1977	40	YCC
301·4·18	10x10'	1976	30	Contract
301·4·19	10x10'	1977	32	Contract
301·4·20	10x10'	1976	37	Contract
301·4·21	10x10'	1979	51	Contract
301·4·22	10x10'	1977	34	Contract
301·4·23	10x10'	1976	14	Contract
301·4·24	10x10'	1976	14	Ravalli Services
301·4·25	10x10'	1976	45	Contract
301·4·27	10x10'	1977	37	Contract
301·4·28	10x10'	1977	19	Contract
301·4·29	10x10'	1977	32	Contract
301·4·30	10x10'	1977	21	Contract
301·4·31	10x10'	1977	12	Contract
301·4·32	10x10'	1977	14	Contract
301·4·33	10x10	1978	24	Contract
301·4·34	10x10'	1978	48	Contract
301·4·35	10x10'	1977	14	Contract
301·4·36	10x10'	1976	21	Force Account
301·4·04	10x10'	1976	2	Ravalli Services
301·5·15	10x10'	1976	85	Contract
301·6·44	10x10'	1976	54	Contract
301·6·46	10x10	1978	36	Force Account
302·5·19	10x10'	1977	16	Force Account
302·5·20	10x10'	1976	26	Force Account
394·4·03	Not Treated			
394·4·04	Not Treated			
394·4·06	Not Treated			
394·4·06	10x10'	1979	36	Contract
394·4·07	Not Treated			

Stand No.	Type	Year	Acres	Labor
394·5·01	Not Treated			
394·5·02	Not Treated			
394·5·03	Not Treated			
394·5·04	Not Treated			
394·5·05	Not Treated			
394·5·06	Not Treated			
395·5·01	7x7'	1974	80	Contract
395·5·02	10x10'	1975	17	Contract
395·5·20	10x10'	1979	13	Force Account
395·5·32	10x10'	1977	41	Contract
395·5·33	10x10'	1976	19	Contract
395·5·34	10x10'	1976	27	Contract
395·5·35	10x10'	1975	17	Contract
395·5·36	10x10'	1976	19	Contract
395·5·37	10x10'	1975	14	Contract
395·5·38	10x10'	1976	118	Force Account
395·5·39	10x10'	1978	32	Contract
395·5·40	10x10'	1978	11	Contract
395·7·01	Not Treated			
395·7·02	10x10'	1978	53	Contract
395·8·11	10x10'	1978	22	Contract
395·8·12	10x10'	1978	30	Contract
395·8·13	10x10'	1979	19	Contract
395·8·14	10x10'	1978	35	Contract
395·8·15	10x10'	1979	41	Contract
395·8·16	10x10'	1977	40	YCC
395·9·04	10x10'	1976	20	Force Account
395·9·05	10x10'	1977	32	Contract
395·9·06	10x10'	1979	46	Contract
395·9·07	10x10'	1979	27	Contract
395·9·08	10x10'	1979	20	Contract
399·5·38	10x10'	1976	96	Force Account
399·5·39	10x10'	1976	12	Force Account
399·5·40	10x10'	1976	13	Force Account

MECHANICAL TREATMENTS - SULA R.D. (CONT.)

Stand No.	Type	Year	Acres	Labor
399·5·41	10x10'	1976	12	Force Account
399·5·42	10x10'	1975	19	Force Account
399·5·43	10x10'	1978	35	Contract
399·5·44	10x10'	1977	41	Force Account
399·5·45	Dominant	1976	35	Force Account
399·5·46	10x10'	1977	10	Force Account
399·6·10	12x12'	1975	33	Contract
399·6·11	Not Treated			
399·6·12	10x10'	1976	53	Contract
399·6·13	12x12'	1975	43	Contract
399·6·14	12x12'	1978	23	Contract
399·6·15	10x10'	1975	10	Force Account
399·6·16	10x10'	1975	20	Force Account
399·6·17	Dominant	1975	12	Force Account
399·6·18	10x10'	1976	17	Force Account
399·6·17	Crop Tree	1976	16	Force Account
399·6·20	10x10'	1976	24	Force Account
399·6·21	10x10'	1977	24	Contract
399·6·22	10x10'	1977	13	Contract
399·6·23	10x10'	1976	15	Force Account
399·6·24	10x10'	1976	10	Force Account
399·6·25	10x10'	1976	21	Force Account
399·6·26	10x10'	1976	16	Force Account
399·6·27	Dominant	1975	5	Force Account
399·6·28	Dominant	1976	11	Force Account
399·6·29	10x10'	1975	55	Force Account
399·6·30	10x10'	1975	22	Force Account
399·6·31	Dominant	1975	9	Force Account
399·6·32	10x10'	1975	7	Force Account
399·6·33	Dominant	1977	13	Force Account
399·6·34	10x10'	1976	7	Force Account
399·6·35	10x10'	1977	35	Force Account
399·6·36	10x10'	1977	10	Force Account
399·6·37	10x10'	1977	24	Force Account

Stand No.	Type	Year	Acres	Labor
399 6 38	Crop Tree	1975	10	Force Account
399 6 39	Crop Tree	1975	10	Force Account
399 7 12	12x12'	1977	40	Contract
399 7 13	12x12'	1976	58	Contract
399 7 14	12x12'	1976	26	Contract
399 7 15	12x12'	1976	67	Contract
399 7 16	12x12'	1975	44	Contract
399 7 17	12x12'	1975	43	Contract
399 8 04	7x7'	1974	21	Purchase Order
399 8 05	7x7'	1974	14	Purchase Order
399 8 06	7x7'	1974	9	Purchase Order
399 8 07	7x7'	1974	15	Purchase Order
399 8 08	7x7'	1974	17	Purchase Order
399 8 09	7x7'	1974	19	Purchase Order
399 8 10	10x10'	1975	22	Contract
399 8 11	10x10'	1976	13	Contract
399 8 12	10x10'	1975	24	Contract
399 8 13	10x10'	1976	35	Contract
399 8 14	10x10'	1975	46	Contract
399 8 15	10x10'	1976	28	Contract
399 8 17	7x7'	1974	3	Purchase Order
399 8 18	7x7'	1974	6	Purchase Order
399 8 19	Dominant	1975	3	Force Account
399 8 20	Dominant	1975	3	Force Account
399 8 21	10x10'	1976	39	Contract
399 8 23	Dominant	1975	8	Force Account
399 8 25	10x10'	1979	44	Force Account
399 9 03	10x10'	1976	25	Contract
399 9 04	10x10'	1976	34	Contract
399 9 05	10x10'	1976	11	Contract
399 9 06	10x10'	1976	14	Contract
399 9 07	10x10'	1976	50	Contract
399 9 08	10x10'	1978	51	Contract
399 9 09	10x10'	1979	50	Contract
399 9 11	10x10'	1979	49	Contract